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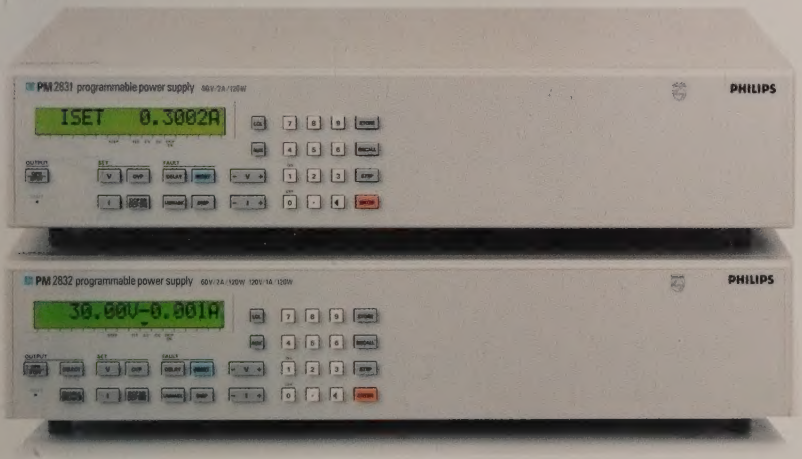
PM2831-PM2832
Programmable Power Supplies

Operation Manual



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PM2831-PM2832

Programmable Power Supplies

OPERATION MANUAL

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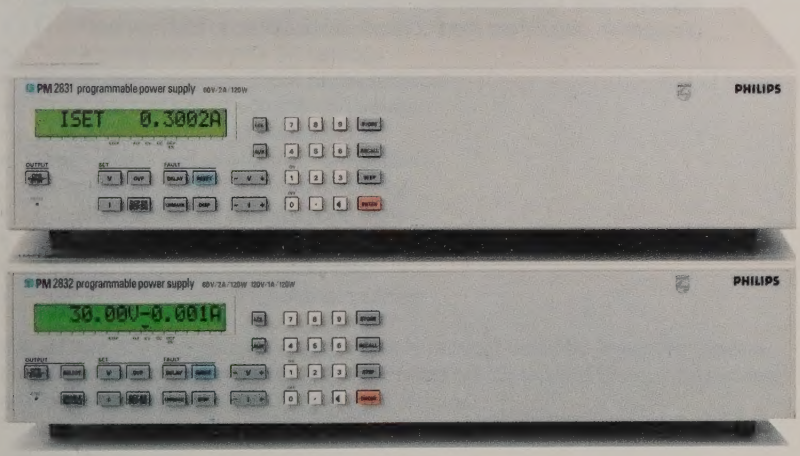

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INITIAL INSPECTION

Check the contents of the shipment for completeness and note whether any damage has occurred during transport. If the contents are incomplete, or if there is damage to the instrument or its accessories, the CLAIM sheet should be filled out immediately. Also the FLUKE/PHILIPS sales or service office nearest to you should be notified to facilitate the repair or replacement of the instrument or accessories. Addresses are published at the back of the Reference Manual.

The following items must be included in the shipment:

Qty	Item	Model number or ordering number
1	Operation manual English	4822 872 80165
1	Reference Manual English	4822 872 80168
1	Operation manual German (only in EURO and SWISS)	4822 872 80166
1	Operation manual French (only in EURO, SWISS and USA)	4822 872 80167
1	Programming card English	4822 872 80169
1	Power cord	
	EURO	5322 321 23297
	SWISS	5322 321 10679
	UK	5322 321 10681
	USA	5322 321 10644
2	Spare fuses	
2	Mounting brackets	

For further information, refer to section 3.2 "Initial inspection".

Items not included in the shipment:

1	Service manual English (to be ordered via your local sales or support office)	4822 872 85001

INSIDE THIS MANUAL

This operating manual has been aimed at the experienced user as well as the user new to Programmable Power Supplies. It will help the reader to use and operate the power supply manually (local operation) or from a PC via the GPIB (remote operation).

1) OPERATOR SAFETY
   Gives full information about safety aspects.

2) INTRODUCTION TO YOUR PROGRAMMABLE POWER SUPPLY
   Describes what your power supply is and how you can use it.

3) INSTALLATION INSTRUCTIONS
   Describes the steps necessary to prepare your power supply for use.

4) GETTING STARTED WITH YOUR PROGRAMMABLE POWER SUPPLY
   Describes how to get started with some commonly used functions of the power supply. A step-by-step tutorial describes how to operate the functions in the local (manual) mode and in the remote mode (from a PC via the GPIB).

5) USING YOUR PROGRAMMABLE POWER SUPPLY
   Gives functional information about how to use the power supply in the local as well as the remote mode.

Additional information is available in the following appendices:

A) ACCESSORIES
   Gives a functional overview of the accessories that are supplied or can be ordered.

B) SCPI CONFORMANCE INFORMATION
   Gives information about versions of the confirmed and approved SCPI commands and queries.

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Guarantee Statement

This Philips guarantee is in addition to all rights which the buyer may have against his supplier under the sales agreement between the buyer and the supplier and according to local legislation.

Philips guarantees this product to be free from defects in material and workmanship under normal use and service for a period of one (1) year from the date of shipment. This guarantee does not cover possible required recalibration and/or standard maintenance actions. This guarantee extends only to the orginal purchaser and does not apply to fuses batteries or to any product or part thereof that has been misused, altered or has been subjected to abnormal conditions of operation and handling.

Fluke/Philips- supplied software is guaranteed to be properly recorded on non-defective media. We will replace improperly recorded media without charge for 90 days after shipment upon receipt of the software. Our software is not guaranteed to be error free.

Philips' obligation under this guarantee is limited to have repaired or replace a product that is returned to an authorised Philips Service Centre within the guarantee period, provided that Philips determines that the product is defective and that the failure has not been caused by misuse, alteration or abnormal operation.

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If a failure occurs, send the product, freight prepaid to the Service Centre designated by Philips with a description of the difficulty. At Philips' option, repairs will be made or the product will be replaced. Philips shall return the product, F.O.B. Repair Centre, transportation prepaid, unless the product is to be returned to another country, in which case the Buyer shall pay all shipping charges, duties and taxes. Philips assumes NO risk for damage in transit.

Disclaimer
The foregoing guarantee is exclusive and is in lieu of all other guarantees, expressed or implied, including but not limited to any implied guarantee of merchantability, fitness, adequacy for any particular purpose or use. We shall not be liable for any direct, indirect, special, incidental, or consequential damages, whether based on contract, tort, or otherwise.
Some countries or states do not allow the foregoing limitations. Other rights may also vary.

1 OPERATOR SAFETY

Read this page carefully before beginning to install and use the instrument. This instrument meets the safety requirements of IEC 348 class 1 and has been supplied in a save condition.

1.1 INTRODUCTION

The instrument described in this manual is designed to be used only by qualified personnel.

WARNING: **Servicing described in this manual is to be done only by qualified service personnel. To avoid electrical shock, do not service the instrument unless you are qualified to do so.**

1.2 SAFETY PRECAUTIONS

For the correct and safe use of this instrument it is essential that both operating and service personnel follow generally accepted safety procedures in addition to the safety precautions specified in this manual. Specific warning and caution statements, where they apply, will be found throughout the manual. Where necessary, the warning and caution statements and/or symbols are marked on the instrument.

1.3 CAUTION AND WARNING STATEMENTS

CAUTION: *Is used to indicate correct operating or maintenance procedures in order to prevent damage to or destruction of the equipment or other property.*

WARNING: **Calls attention to a potential danger that requires correct procedures or practices in order to prevent personal injury.**

1.4 SYMBOLS

Symbol:	Notion of symbol:
	(black) Information about how to preserve the instrument from damage. Refer to the same symbol on the instrument and the explanation in the manual.

1.5 IMPAIRED SAFETY

Whenever it is likely that safety has been impaired, the instrument must be turned off and disconnected from line power. The matter should then be referred to qualified technicians. Safety is likely to be impaired if, for example, the instrument fails to perform the intended power output(s) or shows visible damage.

2 INTRODUCTION TO YOUR PPS

2.1 INTRODUCTION

The basic function of your power supply is to supply a predefined dc voltage or current in a controlled way through an output channel. Your power supply model can have 1 or 2 output channels. Unless stated otherwise, the information in this manual applies to all models. For technical and environmental performance specifications, refer to the REFERENCE manual.

REMOTE OPERATION

The family of Programmable Power Supplies is primarily intended to be used in an automatic system environment programmed via a controller. For that reason the power supplies have been equipped with a GPIB interface and conform to IEEE-488.2 as well as the SCPI 1990.0 standards. For remote operation, refer to section 4.6 (tutorial), section 5.5 (using) or the REFERENCE manual (operating references).

LOCAL OPERATION

The power supplies can also be used in a direct and simple way as a bench-top instrument (stand-alone) via their keypad and display. For local operation, refer to section 4.5 (tutorial), section 5.4 (using) or the REFERENCE manual (operating references).

Family overview

MODEL *)	DESCRIPTION	OUTPUT 1	OUTPUT 2
PM2831/0yz	Single Output system	60V/2A/120W	
PM2831/1yz	Single Output system	120V/1A/120W	
PM2832/0yz	Dual Output system	60V/2A/120W	60V/2A/120W
PM2832/1yz	Dual Output system	120V/1A/120W	120V/1A/120W
PM2832/2yz	Dual Output system	60V/2A/120W	120V/1A/120W

Table 2.1 Power Supply models

*) • y Indicates the instrument's revision number:
y = 1 Standard version.
y = 5 Version with front connection option (see section 3.4.3).
• z indicates the country version:
z = 1 Euro
z = 2 USA
z = 3 UK
z = 4 Swiss

FRONT PANEL

The front panel contains a keypad and LCD display for dialogue with the operator. Via the keypad local operation (manual) of the power supply is done. The display is used for passing information to the operator, such as:

- response information for the operator, e.g. ADDRESS 12
- readback information, e.g. an output voltage and current
- status information, e.g. display of the REM text
- error messages, e.g. the OVERCURRENT message

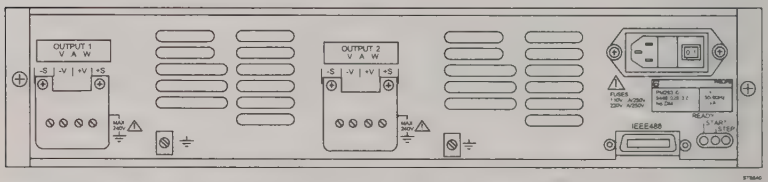
PM283x Frontpanel

REAR PANEL

The rear panel contains connectors for the line power input, the output channel(s), the trigger lines, and the GPIB (IEEE 488) interface. A fan provides forced cooling of each output channel. The line power input module also contains the line fuses, line filter and the power switch.

For remote control, a GPIB (IEEE 488) connector for use with a GPIB controller is been provided.

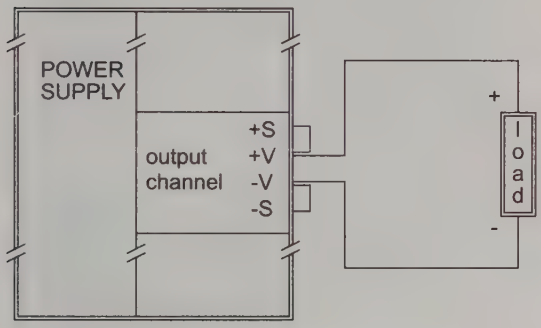
Three SMB connectors for START, STEP, and READY are provided for external triggering of the step mode, recalling stored instrument settings.



PM283x Backpanel

2.2 BASIC OPERATION

The programmable power supplies offer a combination of programming capabilities and a variety of dc output power ratings that make them ideal for power systems applications. The +V and +S as well as the -V and -S terminals have been connected to each other at the factory.



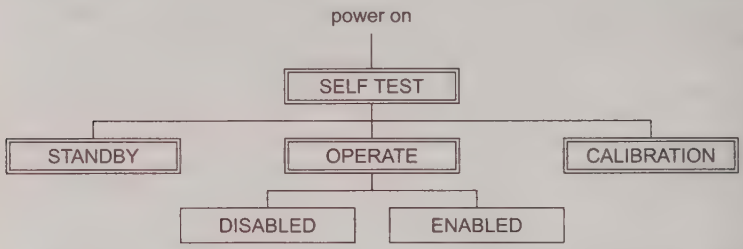
Each output channel can be programmed to the desired dc voltage or dc current (output function). Self-contained measurement and readback capability eliminate the need for externally metering the output channel, using a separate multimeter. The readback voltage and current of the selected output channel can be monitored on the front panel display (measure function). Protective circuitry within your power supply limits or turns off an output channel when an abnormal condition occurs. The following protection features have been implemented:

- OVERVOLTAGE and OVERCURRENT
- UNREGULATED OUTPUT
- OVERTEMPERATURE
- OPEN SENSE
- COUPLED PROTECTION (of output channels)

Each output channel can operate as a **constant voltage** source (**CV mode**) or as a **constant current** source (**CC mode**):

- As a constant voltage source the output voltage remains constant, while the output current changes due to fluctuations of the load.
- As a constant current source the output current remains constant, while the output voltage changes due to fluctuations of the load.

After power on, your programmable power supply performs a selftest. If the selftest is succesful, the STANDBY, OPERATE, or CALIBRATION mode will be entered. In the OPERATE mode, an output channel can be in the ENABLED or DISABLED state.



- SELF TEST — After power on your power supply will test itself. Depending on the Power ON DEFinition (PONDEF), the STANDBY or OPERATE mode is entered. The CALIBRATION mode can be entered manually via the AUX key, when pressed during power up, or remotely via the GPIB controller.

- STANDBY — In this mode your power supply is in standby. This means no power is output, i.e., all output channels have been shut off. It is possible, however, to verify or set voltage and current settings.

- OPERATE — In this mode your power supply is able to output a voltage or a current. For multiple output models each individual output channel can be disabled (DISABLED state) or enabled (ENABLED state). It is also possible to verify or set voltage and current settings.

- CALIBRATION — In this mode your power supply can be calibrated. At the end of the calibration the STANDBY mode will be entered.

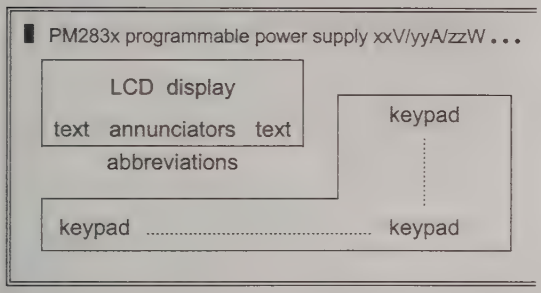
The following diagram shows the possible output channel states:

	OUTPUT CHANNEL	
	DISABLED	ENABLED
Power supply STANDBY	no power	no power
Power supply OPERATE	no power	power output

2.2.1 Local operation

Using the front panel keys, you can program an output channel voltage or current. On the front panel display you can read back the actual voltage and current of the selected output channel. Operating information about the instrument and the selected output channel, as well as output-specific error messages, are shown on the display in the following ways:

- text
- annunciators, pointing at abbreviations on the front panel right below the display.



You can use the keypad as follows to control your power supply:

- control interface and general functions via a menu
- switch between the operate and standby mode
- set the supply to local control (if not remotely locked)
- reset the power supply, i.e., return to the 'power on' state
- store/recall/step voltage and current settings (1 to 99) in the instrument's battery backed-up memory (recall memory)

You can use the keypad as follows to control one of the output channels:

- select an output channel (only for multiple output models)
- enable or disable an output channel (only for multiple output models)
- unmask, delay or display the setting of bits in the fault register
- reset the overvoltage and overcurrent protection

You can use the keypad as follows to perform an output channel setting:

- set or adapt the output voltage or current
- set the overvoltage trip level
- enable or disable the overcurrent protection

2.2.2 Remote operation

Via the General Purpose Interface Bus (GPIB), your programmable power supply can be programmed to receive input data and to send output data. An example for input data (listener) is that a voltage and current can be programmed directly to the selected output channel. An example for output data (talker) is the readback voltage and current of the selected output channel.

2.2.2.1 IEEE 488.2 compatibility

IEEE 488.2 is a new standard that is additional and complementary to the IEEE 488.1 standard. Your programmable power supply conforms to the IEEE 488.2 standard. For more information refer to section 5.3 "Remote Operation" and the REFERENCE manual.

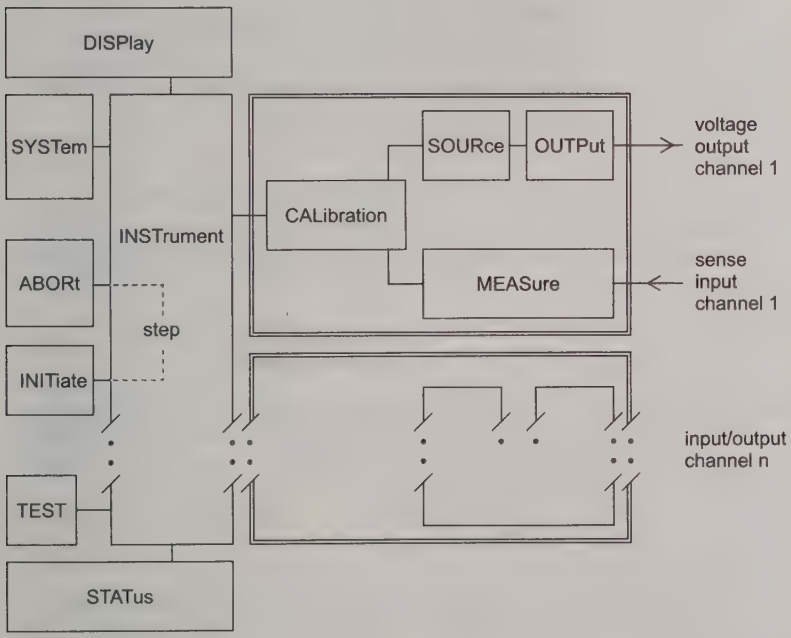
The following common IEEE 488.2 functions have been implemented by means of commands and queries:

	COMMAND	QUERY
■ initialization of your power supply		
• identify your instrument		*IDN?
• reset your instrument	*RST	
• test your instrument		*TST?
■ program synchronization		
• operation complete	*OPC	*OPC?
• wait to continue	*WAI	
■ triggering your power supply		
• trigger your instrument	*TRG	
■ status handling		
• standard event status enable register	*ESE	*ESE?
• standard event status register		*ESR?
• service request enable	*SRE	*SRE?
• status byte register		*STB?
■ store/recall front panel settings		
• save front panel settings	*SAV	
• recall front panel settings	*RCL	
■ specials		
• clear status	*CLS	
• power on status clear	*PSC	*PSC?

2.2.2.2 *SCPI compatibility*

SCPI (Standard Commands for Programmable Instruments) is a command definition standard for programmable test and measurement instruments. Your programmable power supply conforms to the SCPI standard. For more information, refer to section 5.3 "Remote operation" and the REFERENCE manual.

The programmable functions have been implemented via the GPIB by means of the following SCPI subsystems:



- **ABORt**
  This subsystem is used for stopping the step function of the power supply.

- **CALibration**
  This subsystem is used for calibration of the instrument. Your power supply can be calibrated without removing the cover or removing the power supply from your rack measurement set up. This feature allows you to calibrate the power supply at its normal operating temperature. The recommended calibration interval is one year. Refer to the REFERENCE manual for complete calibration details.

- **DISPlay**
  This subsystem is used for control of the front panel display.

- **INITiate**
  This subsytem is used to start up (initiate) the step function of the power supply.

- **INSTrument**
  This subsystem is used for control of the instrument functions.

- **MEASure**
  This subsystem is used for measurement (readback) of output voltage and output current.

- **OUTPut**
  This subsystem is used for control of an output channel.

- **SOURce**
  This subsystem is used for source and setting functions of an output channel, such as : - source definitions
  - voltage (protection) settings
  - current (protection) settings
  - automatic stepping

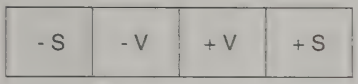
- **STATus**
  This subsystem is used for handling the device-dependent operational and questionable status information.

- **SYSTem**
  This subsystem is used for handling of system and control functions, such as: - lockout frontpanel control
  - define the 'power on clear' behavior
  - request for status information

- **TEST**
  This subsystem is used for testing the instrument.

2.2.3 Sense modes

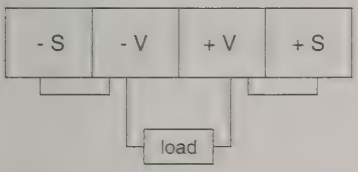
Each output channel has been provided with a set of four terminals. The inner terminals have been marked as **- V(oltage)** and **+ V(oltage)**, while the outer terminals have been marked as **- S(ense)** and **+ S(ense)**.



Each output channel can be connected to a load in two different ways:

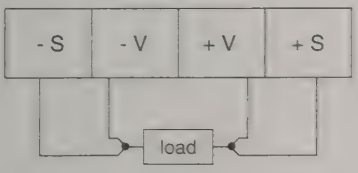
- through the +V and -V terminals, causing the power supply to operate in its local sense mode (see section 2.2.3.1)
- through the +V and -V and +S and -S terminals, causing the power supply to operate in its remote sense mode (see section 2.2.3.2)

2.2.3.1 Local sensing



At delivery the sense terminals are interconnected with the voltage terminals. This is called local sensing. If the voltage drop across both the wires to the load is negligible, the voltage at the load will equal the programmed value.

2.2.3.2 Remote sensing



If the voltage drop across the +V and -V wires to the load is substantial, the voltage at the load will be less than the programmed value. To prevent the voltage at the load from being less than the programmed value, the sense wires must also

be connected to the load (remote sensing). This way of sensing allows the power supply to compensate for voltage drops in the wires between the power supply and the load. The sense wires must be connected directly to the load poles.

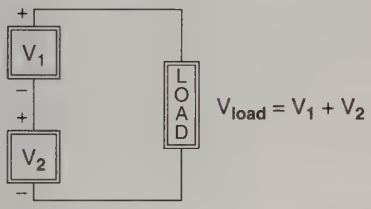
Note: Long sense wires are susceptible to noise pickup. To minimize noise pickup, twist each pair of sense wires together. Shielding around the sense wires may be necessary in more extreme cases.

2.3 ADVANCED OPERATION

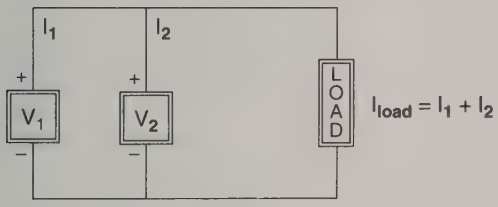
2.3.1 Output channel interconnections

Identical output channels can be connected in the following ways to increase the total output capability:

- In **series** to increase the output voltage capability. Refer to section 5.6.2 "Serial connection of output channels" for more information.



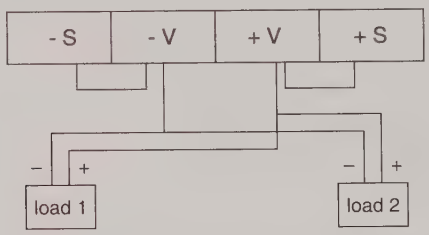
- **Parallel** to increase the output current capability. Refer to section 5.6.1 "Parallel connection of output channels" for more information.



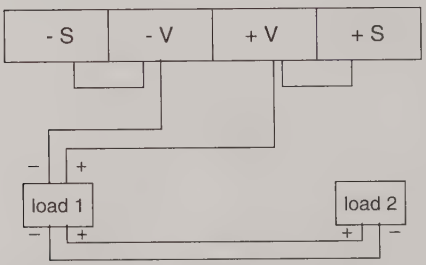
CAUTION: Only outputs with equivalent voltage and current ratings may be connected in series or parallel. For maximum output capacity, refer to section 5.5.1 "Output channel ratings and characteristics". For more information about connections, refer to section 5.6 "Advanced use".

2.3.2 Multiple loads

If more than one load is connected to an output channel, use separate wires to connect each load. This minimizes mutual coupling effects and takes full advantage of the power supply's low output impedance. Each pair of wires should be as short as possible to reduce wire inductance and noise pickup. To prevent the loads from mutually influencing each other, due to load fluctuations. The loads must be connected in parallel, not in series.



CORRECT: Parallel connection of loads



WRONG: Series connection of loads

Note: To prevent noise pickup, you are advised to twist the sense wires and shield them from each other.

In principle there is no restriction about the number of loads that can be connected. Remote voltage sensing is recommended if one load is more sensitive than the other(s); therefore, sense directly at the most sensitive load.

2.4 ACCESSORIES

2.4.1 Supplied with the instrument

	EURO	SWISS	UK	USA
• Operation manual English	YES	YES	YES	YES
• Reference manual English	YES	YES	YES	YES
• Operation manual German	YES	YES		
• Operation manual French	YES	YES		
• Programming Card English	YES	YES	YES	YES

- Power cord
- Two spare fuses
- Mounting brackets

2.4.2 Optional

The following accessories can be ordered via your sales representative:

	Type no:
• GPIB IO software drivers (for PC)	PM2201/0x
• GPIB IO software drivers (for PS/2)	PM2202/0x
• IEEE interface board (for PC)	PM2201/0x or PM2201/9x
• IEEE interface board (for PS/2)	PM2202/0x or PM2202/9x
• IEEE interface cables (.5 meter long)	PM2295/05
• IEEE interface cables (1.0 meter long)	PM2295/10
• IEEE interface cables (2.0 meter long)	PM2295/20
• 19" Rack mount (with other 19" units)	PM9280/03
• Trigger line cable set	PM2392/01

For more information about accessories, refer to Appendix A "Accessories".

2.5 DOCUMENTS REFERENCED

- Safety standards : IEC 1010
  VDE 0411 (version with EURO power cord)
  UL 1244 } version with North
  CSA 22.2 Nr. 231 } American power cord

- EMI standards : VDE 0871 B
  CISPR 11
  IEC 801

- Environmental aspects : MIL-T-28800D

- GPIB interface (remote programming) : IEC 625-1 (ANSI/IEEE Std 488.2 - 1987)
  IEC 625-2 (ANSI/IEEE Std 488.2 - 1987)
  SCPI Std 1990.0

3 INSTALLATION INSTRUCTIONS

3.1 Introduction

This section contains instructions for the following:

- inspecting the contents of the shipment for completeness and/or damage during transport (initial inspection)
- ensuring the safety of the operator
- installing your power supply
- making the input and output connections
- performing the installation acceptance checks

3.2 Initial inspection

Inspect the contents of the shipment for completeness and note whether any damage has occurred during transport. If the contents are not complete, or if there is damage, inform your FLUKE/PHILIPS Sales and Support Center so that repair or replacement of the instrument can be arranged. A full list of these centers is printed at the back of this manual.

Pay special attention to the following parts :

- accessories to be supplied (refer to Appendix B).
- front panel keys and display.
- rear panel connectors and terminal blocks.
- cabinet surfaces.

The shipment must contain one power supply plus the accessories supplied. For a complete list of accessories supplied, refer to the INITIAL INSPECTION page in the front of this manual.

3.3 Operator safety instructions

The instrument has been designed and tested in accordance with IEC Publication 348 for Class 1 instruments and has been supplied in a safe condition. The present Operation Manual contains information and WARNING or CAUTION statements, which must be followed by the purchaser to ensure safe operation and to keep the instrument in a safe condition.

The instrument described in this manual is to be used by properly trained personnel. Adjustment, maintenance, and repair of the exposed equipment must be carried out only by qualified personnel, who are aware of the hazards involved.

Symbol

Before connecting the instrument to the power, ensure that the power ground is functioning correctly. Before any other connection is made, the instrument must be connected to the earth (ground) conductor via the three-conductor power cord. The power plug must be inserted only into a socket outlet provided with ground contact. The grounding protection must not be defeated by use of an extension cord without ground conductor.

WARNING : Any interruption of the protective conductor inside or outside the instrument or disconnection of the protective ground terminal is likely to make the instrument dangerous. Intentional interruption is prohibited.

The instrument is shipped from the factory with a power cord that has a plug appropriate for the country in which it is sold. If a different power plug or power cord is required, contact your Philips/Fluke Sales and Service Center. A list of these centers is printed at the back of this manual.

CAUTION: *When an instrument is brought from a cold into a warm environment, condensation may cause a hazardous condition; therefore, make sure that the grounding requirements are strictly adhered to.*

3.4 Installation

3.4.1 Mechanical installation

The instrument is fan cooled and must be installed in a location that allows sufficient space at the three important sides: rear, left and right. Each side must have a space of at least 1 inch (25 mm). The fan, located at the rear, cools the instrument by drawing air into the openings at the rear and exhausting it through openings on the sides. Each instrument output channel has its own fan.

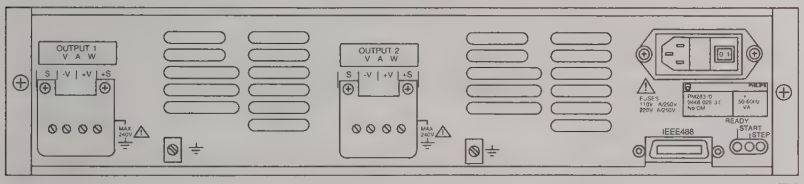
3.4.2 Electrical installation

Pre-installation checks:

- Read chapter 1 "OPERATOR SAFETY" before making any connections.
- Before inserting the power plug into the power supply, ensure that the ground conductor is functioning correctly.

Check that this instrument is suitable for the local situation as indicated on the typenumber plate (sticker) on the backpanel.

NOTE : If the instrument must be wired to the local situation, contact your FLUKE/PHILIPS Sales and Service Center to have it modified. A list of these centers is printed at the back of this manual.



PM2832 Backpanel (Dual output model)

The power inlet module, located at the rear, is an integral power adapter and includes the power input-socket, the holder for the two power fuses and the POWER ON/OFF (1/0) switch. The two power fuses have been located behind the flap next to the power input-socket.

The current ratings of the two power fuses are:

	PM2831	PM2832
115V	1.6 AT	3 AT
230V	3 AT	6.3 AM

WARNING: **When a fuse must be replaced, the instrument must be switched off and disconnected from the power. Refer to Chapter 1 in the Reference Manual.**

3.4.3 Front Connection Unit

Introduction

This section describes the use and capabilities of the Front Connection Unit, mounted underneath the power supply.
The Front Connection Unit provides the interconnections between the rear and front terminals.

The following programmable power supply types have a Front Connection Unit:
- single output unit : PM2831/.5.
- dual output unit : PM2832/.5.

Basic operation

Every output channel has been provided with 4 output terminals, a ground terminal and a SENSE switch.

4 OUTPUT TERMINALS
The inner 2 banana sockets are for the power output, i.e., +V and -V. The outer 2 banana sockets are for the sense input, i.e., +S and -S.

1 GROUND TERMINAL
The ground (earth)terminal has been connected to the housing for grounding and shielding purposes.

1 SENSE SWITCH
This switch enables you to select local or remote sensing.

Note: Switching from remote to local or from local to remote, may cause a sense break detection. To avoid this, it is advised to switch only at power off.

Electrical properties

The maximum voltage between any terminal and the ground : 240 V
The maximum current through an output terminal : 15 A
The maximum current that may be switched : 4 A

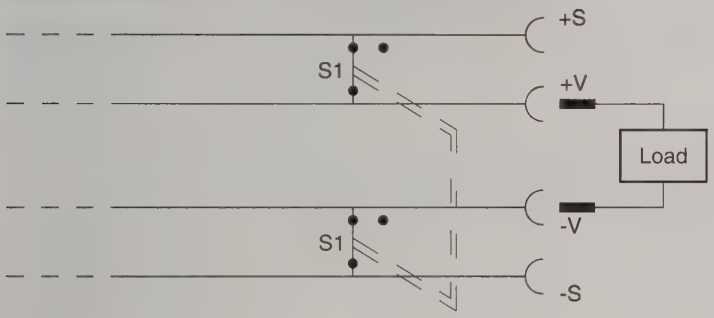
Note: The nominal output voltage range equals output specific ratings, as listed in Table 2.1 of the Operation Manual.

Dimensions and weight

		single unit	dual unit
dimensions:	height	108 mm	108 mm
	width	19 inch = 420 mm	19 inch = 420 mm
	depth	375 mm	375 mm
weight:	net weight	approx.10 kg	approx. 14 kg

Local sensing

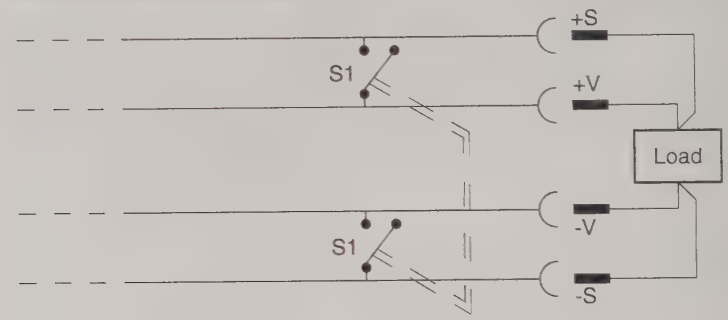
The SENSE switch is in position 'LOCAL' if S1 is 'closed'.

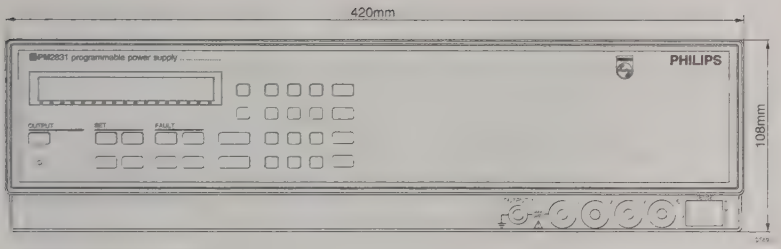


CAUTION: Do not connect a load to the sense terminals +S and -S, because the maximum current through the switch is limited to 4 A. Currents exceeding this limit will damage the switch.
Also take care that the sense wires (used for remote sensing) are disconnected from the sense terminals, to prevent current through the sense switches.

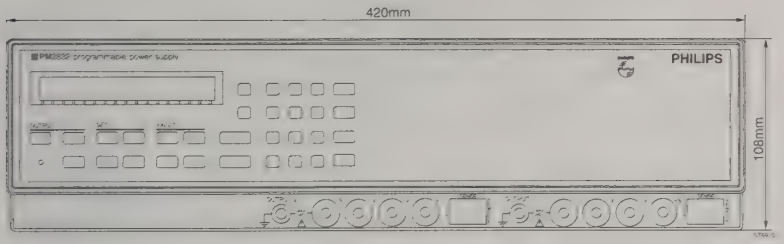
Remote sensing

The SENSE switch is in position 'REMOTE' if S1 is 'open'. The sense terminals must be connected to the load.





Single output model



Dual output model

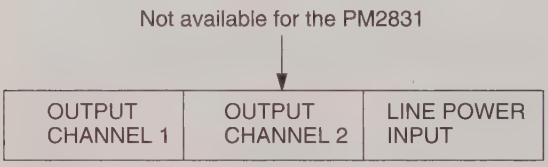
3.5 OUTPUT CONNECTIONS

This section describes the following output connections:

- output channel terminals
- GPIB connector
- trigger bus SMB connectors

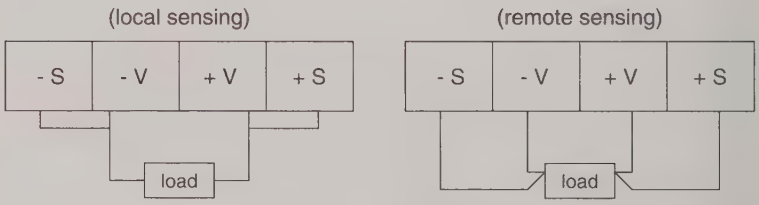
3.5.1 OUTPUT CHANNEL CONNECTIONS

The number of the output channels of the various power supplies is indicated in the last figure of the type number (single, or dual).



Every output channel connector is identical and consists of four terminals, i.e. two Voltage output terminals and two Sense input terminals. A load can be connected in one of the following ways:

- to the + and - Voltage terminals (local sensing)
- to the + and - Voltage and Sense terminals (remote sensing)



WARNING: **To prevent SHOCK HAZARD, turn off the power before making rear output channel connections. All wires and straps must be properly connected with terminal block screws securely tightened. Before any connection can be made, the plastic terminal block cover must be unscrewed and removed. When the connections have been made, the plastic terminal block cover must be reinstalled again.**

3.5.2 GPIB connections

The GPIB (General Purpose Interface Bus) is identical to the IEC 625 or IEEE 488 interface bus. At the rear you will find a 24-pin female connector of which the connector pinning assignment is in accordance with IEEE 488.2 - 1987. An IEEE cable connects your power supply via an IEEE interface board to a controller. For preferred IEEE interface boards and IEEE interface cables, refer to section 2.4.2 "Optional accessories".

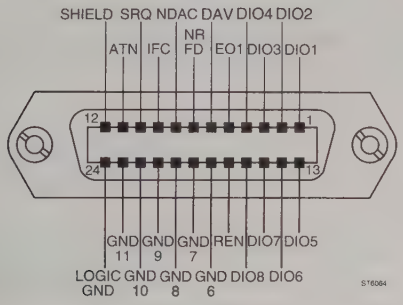


Figure 3.4 Connections IEEE 488/IEC 625

3.5.3 Trigger bus connections

There are three SMB connectors at the rear: START, STEP, and READY.
The modes and functions of the connectors are shown in the following table.

NAME	MODE	FUNCTION
START	input	Enables stepping via the STEP input.
STEP	input	Executes the next step.
READY	output	Indicates whether a step is finished (ready for the next step).

The optional trigger line cables connect your power supply to the instrument which controls the process. For preferred cables, refer to section 2.4.2 "Optional accessories".
The trigger bus connectors can be used to recall output channel settings from the recall memory. For more information, refer to section 5.5.5 "Step functions".

3.6 Acceptance tests

The acceptance tests give you information about the correct operation of the instrument after installation.
The interface test must be performed when using the programmable power supply for remote operation via the Controller/GPIB interface.

3.6.1 Brief check

After turning on your power supply, the following self tests on the hardware parts will be performed automatically:

- ROM test
- RAM test
- GPIB controller test
- Microprocessor timer test
- Communication (D^2B) test
- Display controller test
- ADDA output channel(s) test

The tests will not show up on the display unless an error is detected. In the case of a hardware error, the following text + error code is displayed:

ERROR n:ddd

n = Indication of the error source.
ddd = Summation of the decimal values of the individual errors.

The following error codes are possible:

n = 0: Main CPU error

DECIMAL	ERROR DESCRIPTION
128	Display controller failure.
64	Bank switch failure.
32	Not used.
16	D^2B failure.
8	IEEE controller failure.
4	Processor timer failure.
2	RAM failure.
1	ROM failure.

n = 1: CPU error of output channel 1

DECIMAL	ERROR DESCRIPTION
128	Not used.
64	ROM checksum error.
32	Configuration checksum error.
16	Calibration checksum error.
8	Checksum error of the default settings..
4	Processor timer failure.
2	Not used.
1	Output channel not responding.

n = 2: CPU error of output channel 2

identical to n = 1

If the display is correct, character # will be displayed on the sixteen character positions. Also the text (ENABLED 1 2 3 4 5 6 7 ▼▼▼▼▼▼▼ REM SRQ) will be displayed for1 second.

Next the text INITIALIZING will be displayed for one second. If the mode after power on is OPERATE, the readback voltage and current will be displayed, if the output is not DISABLED.
If not in OPERATE mode, the display shows STANDBY.

If a failure occurs during one of the tests, inform your FLUKE/PHILIPS Sales and Support Center so that repair or replacement of the instrument can be arranged. A full list of these centers is printed at the back of this manual.

These tests take a few seconds to run. The instrument will be ready for use when the message STANDBY or the readback voltage and current appears on the display.

3.6.2 Interface check

To perform the GPIB interface check, the power supply must be connected to the controller via the GPIB; therefore, you need a GPIB interface card + software GPIB drivers + a programming language. For preferred GPIB IO drivers and GPIB hardware interface, refer to section 2.4.2 "Optional accessories".

The various parts of the following interface check must be executed sequentially. Your power supply goes to the remote state when the first command is sent via the GPIB. However, the results of programmed commands can still be monitored on the display, e.g., the readback voltage and current. Also the text REM will be displayed in the remote state.

The interface check consists of the following parts:

- Check the GPIB address setting under the AUX menu.
- send → *IDN? 'Identification query
- read ← PHILIPS,PM281n/xy,0,Va.b

  Notes:
  - *n = 1 or 2*
  - *x is the model indication*
  - *y is the hardware version*
  - *a.b = the firmware version*

- send → *TST? 'Read result of power on test.
  read ← <response_string>
  IF <response_string> = 0 THEN test result is correct
  ELSE display controller failure

- send → :TEST:SYSTEM? 'Selftest power supply query.
  read ← <response_string>
  IF <response_string> = 0 THEN test result is correct
  ELSE the <response_string> = hardware error number

- send → :INST:NSEL 1 'Select output channel 1 (only for multiple output models).

  send → :TEST:INSTRUMENT? 'Selftest of the output channel 1.
  read ← <response_string>
  IF <response_string> = 0 THEN test result is correct
  ELSE the <response_string> = hardware error number
  Repeat this check for all available output channels.

Note: For meaning of the hardware error numbers, refer to section 3.6.1 "Brief check" or the REFERENCE manual "Error messages".

The following check can be executed for all available output channels. A choice has been made for output channel 1 of a multiple output model. For single output models, the output channel does not have to be selected and the channel indication will not be displayed.

- Use the SELECT key to select the output channel to be displayed (only for multiple output models).

- send → :INST:NSEL 1 'Select output channel 1.

- send → :OUTP:STAT ON 'Enable selected output channel.

  Read on the display: **1 STANDBY**
  ENABLED 1 **REM**

- send → :INST:STAT ON 'Set power supply in OPERATE mode.

  Read on the display: **1 xx.xxV yy.yyA**
  ENABLED 1 **REM**

Note: The channel indication (n) and the text "ENABLED n" will only be displayed for multiple output models.

If a failure occurs during one of the GPIB interface tests, inform your FLUKE/ PHILIPS Sales and Support Center so that repair or replacement of the instrument can be arranged. A full list of these centers is printed at the back of this manual.

3.6.3 Performance Verification

If the brief check (section 3.6.1) and the interface check (section 3.6.2) pass successfully and without error messages, you may carry out a performance check before starting to use the power supply.
The REFERENCE MANUAL, APPENDIX B gives you a complete and simple procedure to verify the performance of your power supply.

4 GETTING STARTED

4.1 INTRODUCTION

This chapter will help the user new to programmable power supplies.

First, by describing how to get started with your power supply and learn more about it.

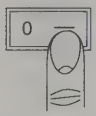
Then, by means of a step by step tutorial on how to operate a few commonly used functions manually (local operation).

Finally, by means of a step by step tutorial on how to program a few commonly used functions via a PC (remote operation).

4.2 INITIAL SETUP OF YOUR POWER SUPPLY

4.2.1 Power up routine

WARNING: **Before you turn on your power supply, make sure that the power input voltage matches the power voltage specifications on the type plate at the rear of your power supply. Refer to section 3.4.2 "Installation" for instructions on how to check this.**



Turn the power on by means of the switch at the rear. The power supply performs a series of self tests that lasts about 5 seconds.

4.2.1.1 Normal self test indications

After the power supply has executed the self tests, all characters and annunciators will be displayed, followed by the message **INITIALIZING**. At the end of the self tests, the supply is in the standby mode (**STANDBY** displayed) or in the operate mode (actual voltage and current displayed).

4.2.1.2 Self test errors

If a power-on self test fails, all output channels will remain disabled, and the display will indicate the type of failure and the output channel on which it occurred. If this is the case, refer to section 3.6 "Acceptance tests".

4.2.2 Instrument identification

Your power supply can be identified by its type number and version number. At delivery it has a default IEEE device address. To identify your power supply, proceed as follows:

1) Start up the identification by pressing:

   the AUX key as many times as necessary to dislay the following:

   ADDRESS aa

   Note: The address aa is the actual GPIB device address (default = 28).

2) Proceed the identification by pressing:

   the AUX key again so that the display shows the following:

   PM283n Sx.x y:zz

   Note : - PM283n is the type number of your power supply.
   - Sx.x is the firmware version of your power supply.
   - y is the number of the output channel (1 or 2).
   - zz is the firmware version of the output channel.

   The firmware versions of all output channels can be verified by pressing

   SELECT to change Y (output channel number) on the display.

Note: The SELECT function is only applicable for multiple output models.

3) Finish the identification by pressing: ENTER .

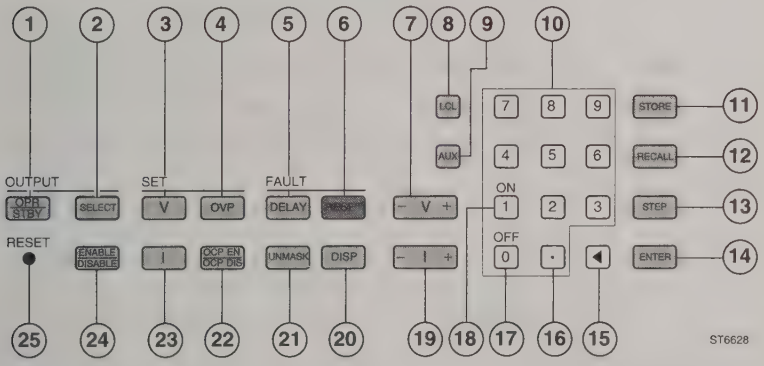
4.3 FRONT PANEL LAYOUT

The following sections describe how to use the front panel control keys in combination with the 16-character display and the annunciators concerned. To be able to use the front panel keys, the power supply must be in the local mode. If the supply is in the remote mode (REM text displayed), press LCL .

If the power supply does not react on pressing the LCL key, this key is disabled remotely by the Local Lockout (LLO) command from the GPIB controller.
In the remote mode pressing the front panel keys will have no effect on programmed settings. It is, however, possible to view the actual settings on the front panel display, using the front panel keys SELECT, V, I, OVP, DELAY, UNMASK, DISP, and AUX.

4.3.1 Keyboard controls

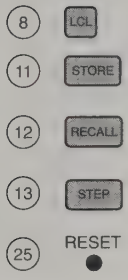
The front panel keyboard controls the following power supply functions:



FUNCTION	KEY	DESCRIPTION
OUTPUT control	(1) OPR STBY	Toggle between OPERATE and STANDBY.
	(2) SELECT	Select an individual channel (only applicable for multiple output models).
	(24) ENABLE DISABLE	Enable/disable the selected channel (only applicable for multiple output models).
SET output	(3) V	Verify/set the output voltage of the selected channel.

	23	I	Verify/set the output current of the selected channel.
	4	OVP	Verify/set the overvoltage trip level of the selected channel.
	22	OCP EN OCP DIS	Enable/disable the overcurrent protection of the selected channel.
FAULT handling	5	DELAY	Verify/set the reprogramming delay
	21	UNMASK	Verify/set the bit mask of the fault register.
	20	DISP	Show the contents of the fault register.
	6	RESET	Reset the overvoltage/overcurrent/fail protection.
Adjust output	7	− V +	Adjust the output voltage of the selected channel. *)
	19	− I +	Adjust the output current of the selected channel. *) *) Only in OPERATE mode.
Numeric input	10	0 ... 9	Input a decimal number.
	17	0 **OFF**	Turn off key.
	18	1 **ON**	Turn on key.
	16	.	Input a decimal point.
	15	◀	Erase previous key stroke (backspace) or leave the STEP function.
	14	ENTER	Enter the input value or exit the current function.
Instrument control	9	AUX [1]	Step through the following control functions: a) Enter the STEP MENU function (press ENTER). - Set AUTO STEP function on or off. - Program the step TIME INTerval. - Set CONTINUOUS step function on or off. - Define START AT entry of loop sequence. - Define STOP AT entry of loop sequence. b) COUPLE voltage and current PARAmeters.

c) COUPLE PROTection of all output channels.
d) Set STandBY AT Power ON behavior on or off.
e) Adjust the CONTRAST of the display (0-9).
f) LOCK the KEYboard [2].
g) Verify/set the GPIB ADDRESS (0 - 30).
h) Verify the identity and firmware version of the power supply + its output channel(s).
i) Verify/set the CALlibration access CODE



Switch the power supply to local control.

Store the voltage and current settings of all output channels (99 store addresses).

Recall the stored voltage and current settings from all output channels (99 recall addresses).

Step from one recalled group of settings to the next group of settings.

Pencil point operation push button to reset the power supply while power is on.

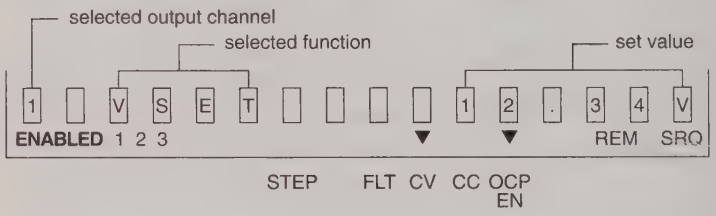
1) The CALIBRATION mode is entered when you turn on the power supply while pressing the AUX key.

2) To unlock the keyboard, press the ENTER key for approximately 5 seconds.

4.3.2 Display indicators

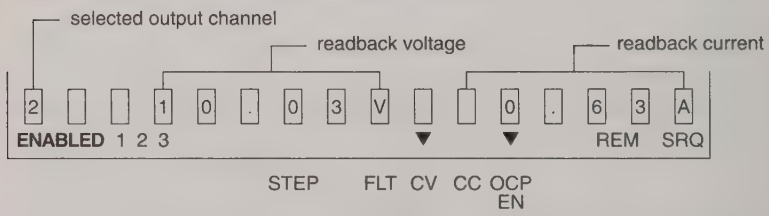
In the OPERATE mode, the display can show up to 16 characters, which are refreshed 4 times per second
On the front plate just below the display a number of status abbreviations, e.g., CV (Constant Voltage), have been placed. Above each status abbreviation an annunciator (▼ sign) can be displayed to indicate the validity of the corresponding status abbreviation.
Also the enabled output channels (1 - 3) in the OPERATE mode plus the REM and SRQ status abbreviations can be displayed.

Example of a voltage setting (V_{set}) for output channel 1:



Note: The output channel indication is displayed only for multiple output channel models.

Example of readback data for output channel 2:



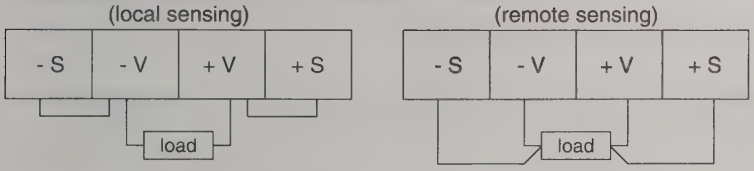
Note: The output channel indication is displayed only for multiple output channel models.

4.4 OUTPUT CHANNEL CONNECTIONS

WARNING: **To prevent SHOCK HAZARD, turn off the line power before making output channel connections, or disable the output channel concerned. All wires and straps must be properly connected, and terminal block screws must be securely tightened. Before any connection can be made, the plastic terminal block cover must be unscrewed and removed. When the connections have been made, the plastic terminal block cover must be fixed again.**

Each output channel has been provided with a set of four terminals. The inner two have been marked as **- V(oltage)** and **+ V(oltage)**, while the outer two have been marked as **- S(ense)** and **+ S(ense)**. At delivery the +V and +S, as well as the -V and -S terminals have been interconnected by straps.

Rear view of an output channel connected to a load:



The voltage at the sense terminal(s) equals the programmed value. The voltage at a connected load may differ from the programmed value, because of a voltage drop depending on the resistance of the wires to the load and the current through the load.
If the voltage drop is negligible, the load wires only have to be connected to the +V and -V terminals. This is called 'local sensing'.
However, if the voltage drop is significant, the voltage at the load can differ from the programmed value. To prevent this, the straps between the +V and +S and -V and -S terminals must be removed and the load wires must also be connected to the +S and -S terminals. This is called 'remote sensing'.

Note: *The terminals have been shielded with a plastic block cover, which must be removed, before any connection can be made.*

WARNING: **To avoid FIRE HAZARD, select a wire large enough to carry short-circuit current without overheating. Two factors must be considered when selecting the wire size for load connections:**
- Conductor temperature, i.e., the current-carrying capacity.
- Total voltage drop, i.e., the wire length and thickness.

4.5 TUTORIAL FOR LOCAL OPERATION

The various parts of this tutorial must be executed sequentially. Before starting with this tutorial, make sure the power supply is in the local state. If the supply is in the remote state (REM is displayed), press [LCL] . If the REM text does not disappear, the LCL key is disabled remotely by the Local Lockout (LLO) command from the GPIB controller.

If the display shows the measured output voltage and current of one of the output channels, the power supply is in the OPERATE mode. Before starting with the tutorial, set the power supply in the STANDBY mode by pressing the OPR/STBY key.

Notes:
- *For multiple output models the selected output channel number n will be displayed.*
- *For a single output model the number n will not be displayed.*

4.5.1 Selecting an output channel

Make an output channel active as follows.
If you have a single output model, skip the first three lines of the following sequence.

Press [SELECT] to select the wanted output channel.

The display then shows the selected output channel.

Press [ENABLE DISABLE] to enable the selected output (if not already enabled).

The display shows: **n STANDBY**
ENABLED n

Press [OPR STBY] to set the power supply in OPERATE mode.

The display shows: **n xx.xx V yy.yy A**
ENABLED n

4.5.2 Setting an output voltage

Do not connect any load. The +V and +S terminals must be interconnected as well as the -V and -S terminals.

1) Set the voltage of the selected output channel to 10 Volts by pressing:

   [V] [1] [0]

   The display shows: **n VSET 10 V**

2) Enter the output voltage setting by pressing [ENTER]

   Check that the display reads approximately 10 Volts. Also check that the CV annunciator is on, indicating that the selected output channel is in the 'Constant Voltage' mode.

3) Program the overvoltage trip level to 19 Volts by pressing:

   [OVP] [1] [9]

   The display shows: **n OVSET 19 V**

4) Enter the overvoltage trip level setting by pressing [ENTER]

5) Set the voltage of the selected output channel to 20 Volts by pressing:

   [V] [2] [0]

   The display shows: **n VSET 20 V**

6) Enter the output voltage setting by pressing [ENTER] and

   check that the display reads: **n OVERVOLTAGE**

7) Set the output voltage to 12 Volts and reset the overvoltage protection by pressing:

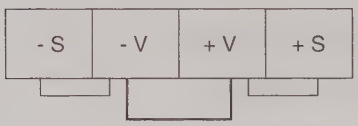
   [V] [1] [2] [ENTER] [RESET]

   Check that the display reads approximately 12 Volts.

4.5.3 Setting an output current

1) Turn off the power supply.

2) Remove the plastic terminal block cover from the output to be tested. Connect a short circuit (jumper wire) between the - V(oltage) and + V(oltage) output terminals as follows:



Note: The diameter of the jumper wire must be large enough to carry the maximum short circuit current.

3) Turn on the power supply. If the supply is in the STANDBY mode or if the selected output channel is disabled, repeat the tutorial commands given in section 4.5.1.

4) Check that the CC annunciator is on, indicating that the output channel is in the 'Constant Current' mode.

5) Set the current of the selected output channel to 0.5 A by pressing:

[I] [.] [5]

The display shows: **n ISET 0.5 A**

6) Enter the output current setting by pressing [ENTER] and

check that the display reads approximately 0.5 Amperes.

7) Enable the overcurrent protection circuit (OCP) by pressing:

[OCP EN / OCP DIS]

8) The display shows: **n OVERCURRENT**
The OCP EN annunciator is on, indicating that overcurrent protection is enabled. The CC annunciator should be off.

9) Disable the overcurrent protection and reset the output channel by pressing:

OCP EN / OCP DIS | RESET

Check that the display reads approximately 0.5 A.
Also check that the CC annunciator is on, indicating that the output channel is in the 'Constant Current' mode again.

10) Turn off the power supply.

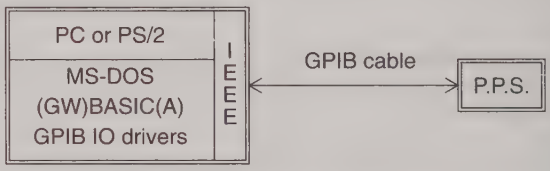
11) Remove the plastic terminal block cover from the output tested and remove the jumper wire between the - V(oltage) and + V(oltage) output terminals.

4.6 TUTORIAL FOR REMOTE OPERATION

To perform this tutorial you need a GPIB controller (PC) with GPIB (IEEE 488 interface) installed, GPIB driver software, and a programming language. The Philips/Fluke GPIB IO drivers provide the hardware interface and software drivers. BASICA or GWBASIC (or QuickBASIC) has been chosen as programming language.

The various parts of this tutorial should be executed sequentially. Your power supply goes into REMote when the first command is sent via the GPIB. However, the results of programmed commands can still be monitored on the display, e.g., the readback voltage and current. Also the text REM will be displayed in the remote state.

Tutorial setup:



Before starting this tutorial, the following must be done or checked:

1) An IEEE interface card must be installed in the controller, e.g.:
   - the PM2201 interface board for PC or PS/2 model 30 controllers
   - the PM2202 interface board for PS/2 model 50 (and higher) controllers

   Note: For more information, refer to Appendix A "Accessories".

2) Connect the power supply to the controller via an IEEE interface cable.

3) Make sure that one of the BASIC interpreters GWBASIC or BASICA and the PM2201 (for PC) or PM2202 (for PS/2) 'GPIB IO' drivers are installed.

4) Load the BASIC and the 'GPIB IO' drivers by typing the following command:
   `IO GWBASIC` or **`IO BASICA`** ↵

5) Load the drivers declaration file DECL.BAS by typing the following command:
   `LOAD "DECL"` ↵

6) Press **`RUN`** to execute the drivers declarations.

7) Execute the following initial commands:

```
DA = 728                    'at delivery GPIB address = 28
ADP = 7 : SC = 1
CALL IOINIT (ADP, SC) 'initiation of the GPIB IO drivers
TIMEOUT = 10.0              '10 seconds time out
CALL IOTIMEOUT (ADP, TIMEOUT)
COMM$ = "*RST"              'reset power supply command
L = 4
CALL IOOUTPUTS (DA, COMM$, L)
```

Check that REM is displayed.

4.6.1 Selecting an output channel

Select one of the possible output channels (**applicable only for multiple output models**), and program it in the OPERATE mode as follows:

1) Select output channel 2 as follows:

```
COMM$ = ":INST:NSEL 2"
L = LEN(COMM$)
CALL IOOUTPUTS (DA, COMM$, L)
```

Select output channel 2 to be displayed by pressing SELECT.

2) Enable output channel 2 as follows:

```
COMM$ = ":OUTP:STAT ON"     'enable selected output channel
L = LEN(COMM$)
CALL IOOUTPUTS (DA, COMM$, L)
```

The display shows: **2 STANDBY**
ENABLED 2 REM

3) Program your power supply in the OPERATE mode as follows:

```
COMM$ = ":INST:STAT ON"          'set OPERATE mode
L = LEN(COMM$)
CALL IOOUTPUTS (DA, COMM$, L)
```

The display shows: **2 xx.xxV yy.yyA**
ENABLED 2 REM

4.6.2 Programming an output voltage

Do not connect any load. The +V and +S terminals must be interconnected as well as the -V and -S terminals.

1) Program the voltage of the selected output channel to 10 Volts as follows:

```
COMM$ = ":SOUR:VOLT 10"
L = LEN(COMM$)
CALL IOOUTPUTS (DA, COMM$, L)
```

Check that the display reads approximately 10 Volts. Also check that the CV annunciator is on, indicating that the selected output channel is in the 'Constant Voltage' mode.

2) Program the overvoltage trip level to 18 Volts as follows:

```
COMM$ = ":SOUR:VOLT:PROT 18"
L = LEN(COMM$)
CALL IOOUTPUTS (DA, COMM$, L)
```

3) Program the voltage of the selected output channel to 20 Volts as follows:

```
COMM$ = ":SOUR:VOLT 20"
L = LEN(COMM$)
CALL IOOUTPUTS (DA, COMM$, L)
```

Check that the display reads: **n OVERVOLTAGE**

4) Set the output voltage to 12 Volts and reset the overvoltage protection as follows:

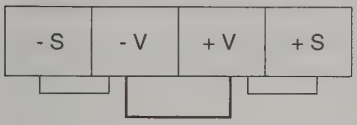
```
COMM$ = ":SOUR:VOLT 12"
L = LEN(COMM$)
CALL IOOUTPUTS (DA, COMM$, L)
COMM$ = ":OUTP:PROT:CLEAR"      'reset protection command
L = LEN(COMM$)
CALL IOOUTPUTS (DA, COMM$, L)
```

Check that the display reads approximately 12 Volts.

4.6.3 Programming an output current

1) Turn off the power supply.

2) Remove the plastic terminal block cover from the output to be tested. Connect a short circuit (jumper wire) between the - V(oltage) and + V(oltage) output terminals as follows:



Note: The diameter of the jumper wire must be large enough to carry the maximum short circuit current.

3) Turn on the power supply. If the supply is in the STANDBY mode or if the selected output channel is disabled, repeat the tutorial commands given in section 4.6.1.

4) Check that the CC annunciator is on, indicating that the output channel is in the 'Constant Current' mode of operation.

5) Program the current of the selected output channel to 0.5A as follows:

```
COMM$ = ":SOUR:CURR 0.5"
L = LEN(COMM$)
CALL IOOUTPUTS (DA, COMM$, L)
```

Check that the display reads approximately 0.5A.

6) Enable the overcurrent protection circuit as follows:

```
COMM$ = ":SOUR:CURR:PROT:STAT ON"'enable protection command
L = LEN(COMM$)
CALL IOOUTPUTS (DA, COMM$, L)
```

7) The display shows: **n OVERCURRENT**
The OCP EN annunciator is on, indicating that overcurrent protection is enabled. Also the CC annunciator must be off.

8) Disable the overcurrent protection and reset the output channel as follows:

```
COMM$ = ":SOUR:CURR:PROT:STAT OFF"'disable protection command
L = LEN(COMM$)
CALL IOOUTPUTS (DA, COMM$, L)
COMM$ = ":OUTP:PROT:CLEAR"        'reset protection command
L = LEN(COMM$)
CALL IOOUTPUTS (DA, COMM$, L)
```

Check that the display reads approximately 0.5A.
Also check that the CC annunciator is on, indicating that the output channel is in the 'Constant Current' mode again.

9) Turn off the power supply.

10) Remove the plastic terminal block cover from the output tested and remove the jumpertv wire between the - V(oltage) and + V(oltage) output terminals.

5 USING YOUR PROGRAMMABLE POWER SUPPLY

5.1 Introduction

This chapter contains functional information about using your programmable power supply (PPS). If covers basic information, such as connecting a load to an output channel, but more advanced information such as the following is also covered:

1) Connecting loads in parallel to an output channel

2) Connecting output channels in series to a load to increase the maximum output voltage or connecting them in parallel to a load to increase maximum the output current.

This chapter also contains information about main operating features and describes how to use those features. You can use your programmable power supply in one of the following ways:

1) In a system environment, via a system controller (PC + IEEE interface). This is called "remote operation".

2) As a bench-top instrument, using the front panel keys, indicators and display. This is called "local operation".

Each output channel of the power supply is a dc power source with controlled limits for power, voltage, and current. An output channel can operate as a constant voltage (CV) source or as a constant current (CC) source, depending on voltage/current settings and load conditions. The maximum output voltage or current is limited by the following:

1) The maximum voltage and current cannot exceed the output channel-specific limits.
2) The product of voltage and current cannot exceed the output channel-specific power limit according to the formulae Vset x Iset ≤ Pmax.

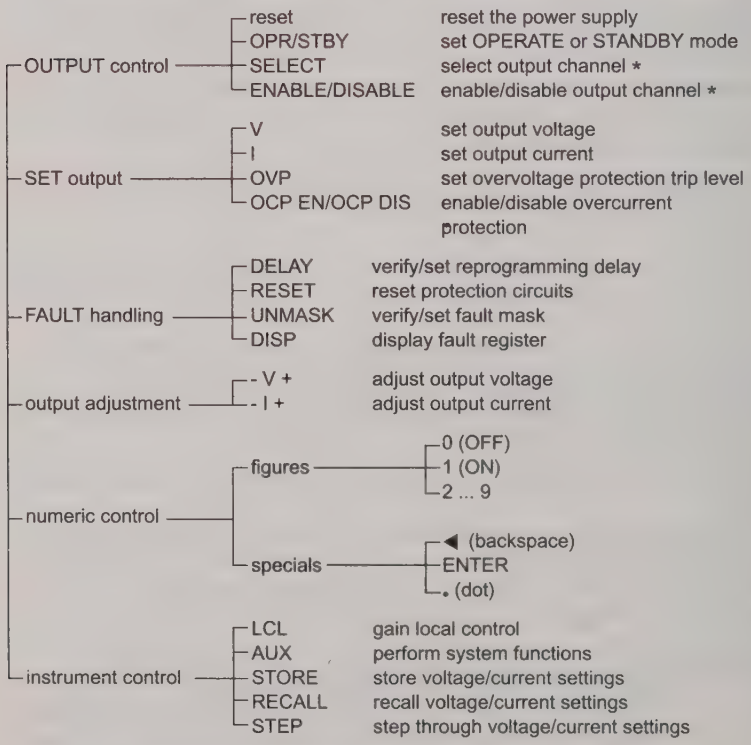
For output limits, refer to section 5.5.1 "Output channel ratings and characteristics".

CAUTION: You may turn on your power supply, if you are sure that the installation instructions, as described in Chapter 3, have been followed. The power supply is ready for use within a few seconds after is is turned on. After a warm-up time of 30 minutes, your PPS meets the specifications listed in the REFERENCE manual.

5.2 Local operation

Local operation of your power supply is done through the front panel keys and display. Operational and error information is shown on the display. The keys are used for operator communication and have been placed into functional groups. This makes the functional use of your power supply very easy:

- OUTPUT control : control over the output channels
- SET output : setting a channel output
- FAULT handling : fault handling per output channel
- output adjustment : adjusting a channel output
- numeric control : input of figures or special keys
- instrument control : control over the instrument



Note: * = *applies to multiple output models only.*

5.3 Remote operation

In the remote mode, pressing the front panel keys will have no effect on programmed settings. It is, however, possible to view the actual settings on the front panel display, using the front panel keys SELECT, V, I, OVP, DELAY, UNMASK, DISP, LCL, and AUX.

5.3.1 Introduction to SCPI

What is SCPI ?

SCPI (Standard Commands for Programmable Instruments) is a standardized set of commands to be used for remote control of programmable test and measurement instruments. It defines the syntax and semantics that the controller must use to communicate with an instrument, and is implemented in the instrument's firmware.

This chapter is an overview of SCPI, as also implemented in Philips test and measurement instruments.

SCPI is based upon the IEEE 488.2 standard. As such it owes much of its structure and syntax, although it has been designed to be used with any of the standard interfaces, for example GPIB (=IEC 625/IEEE 488), VXI and RS232.

The History behind SCPI

Since the introduction of the IEC 625/IEEE 488, "Digital Interface Standard for Programmable Instrumentation", many test and measurement instruments have been supplied with this interface, often referred to as GPIB interface. The GPIB specification sets a standard for, connecting instruments and controllers, and data exchange protocol. But, it did not specify the meaning of the information sent. Instrument manufacturers were free to invent commands as they developed new instruments.

With the updating of the original standard to IEC 625-1/IEEE 488.1-1987 and the introduction of IEEE 488.2-1987, "Codes, Formats, Protocols and Common Commands for use with ANSI/IEEE Std 488.1-1987", a small set of so-called 'common commands' were defined. These commands were intended only for general house keeping purposes. IEEE 488.2 also describes how to send commands to instruments and how the instruments should send responses. However, it did not specify command names and command functionality.

Reason for SCPI

SCPI defines a standard set of instrument programming commands and responses next to the IEEE 488.2 defined commands. For each instrument function, SCPI defines a specific command set. The advantage of SCPI is that programming an instrument is only function dependent and no longer instrument dependent. Several different types of instruments, for example an oscilloscope, a counter and a multimeter, can implement the same function, for example frequency measuring. If these instruments are SCPI compatible, you can use the same commands for all three instruments to perform a frequency measurement, although there may be differences with respect to accuracy, resolution, speed and so forth.

Compatibility

SCPI provides two types of compatibility:

- Vertical
  This means that all instruments of the same type have identical controls. For example, oscilloscopes will have the same controls for timebase, triggers and voltage settings.
- Horizontal
  This means that instruments of different types, that perform the same functions, have the same commands. For example, a DMM and an oscilloscope can both perform a voltage measurement with the same commands.

Management and maintenance of programs

SCPI simplifies maintenance and management of the programs. Today changes and additions in a good working program are hardly possible due to the great diversity of program messages and instruments. Programs are, for other people than the original programmer, difficult to understand, after some time even no longer by the programmer himself. A programmer with SCPI experience will understand, because of his knowledge of the standard, rather quickly the meaning and reasons of a SCPI program. Changes, extensions and additions are much easier to achieve in an existing application program. SCPI is a step towards portability of instrument programming software and, as a consequence, allows the exchange of instruments.

The SCPI consortium

The industry standard "SCPI" is published by an international consortium, which consists of all major manufacturers of test and measurement instruments in the world. Philips is a sponsor member in the SCPI consortium.

Related standards under SCPI

SCPI builds on the IEEE 488.1 and IEEE 488.2 standards, as the following diagram shows:

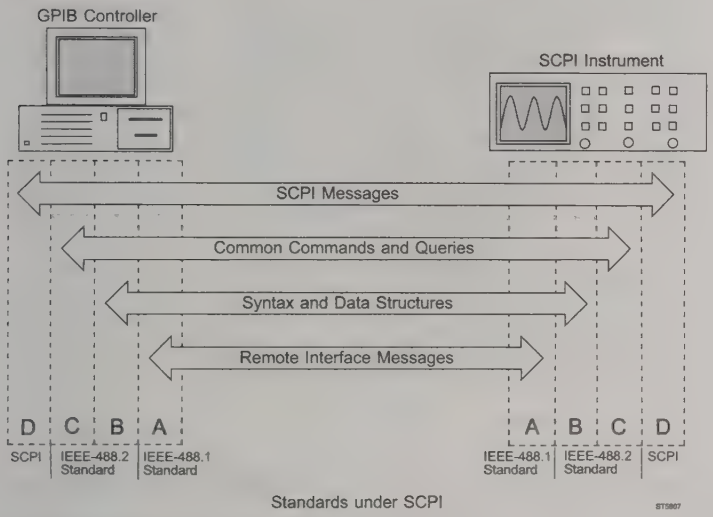


Figure 5.3.1 Standards under SCPI

Figure 5.3.1 shows the different hierarchical levels of communication between a SCPI instrument and the GPIB controller: from the lowest level (level A), such as handshaking on the GPIB, addressing and de- addressing of instruments, up to the highest level (level D), which are the SCPI defined commands and responses.

How does SCPI work in the instrument

SCPI compatibility is obtained by the functions implemented inside an instrument that control the instrument operation. Figure 5.3.2 gives a simplified logical model of the message flow inside a SCPI instrument.

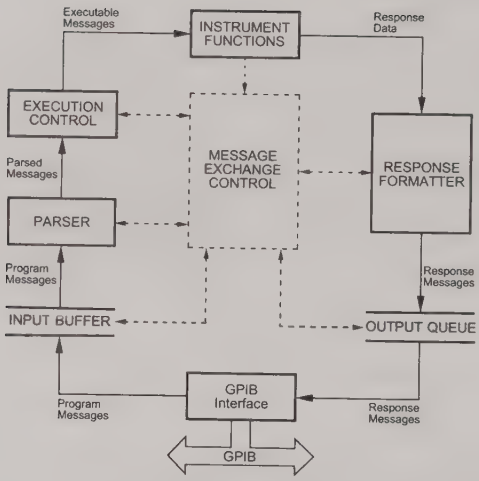


Figure 5.3.2 SCPI message flow model

When the controller sends a message to a SCPI instrument, the following happens:

- The GPIB controller addresses the instrument as listener, the GPIB interface function places the message in the Input Buffer.
- The Parser fetches the message from the Input Buffer, parses (decodes) the message and checks for the correct syntax. Incorrect syntax will cause command errors to be reported via the status system to the controller. Moreover, the parser will detect whether a response is required. This is the case when the input message is a so-called query (ending with a "?").
- The Parser will transfer the executable messages to the Execution Control block in token form (internal codes). The Execution Control block will gather the information required for a device action and will initiate the requested task at the appropriate time. Execution errors are reported via the status system.
- The Instrument Functions block will perform the requested actions.
- If a query was received, the Instrument Functions block will transfer the response data (internal code) to the response formatter.
- The Response Formatter converts internal codes to response messages as transferred over the GPIB and places them in the Output Queue.
- When the GPIB interface is addressed as talker, it takes data from the Output Queue and sends them over the GPIB to the controller.

Message Exchange Control protocol

Another important function is the Message Exchange Control, which is defined by IEEE 488.2. The Message Exchange Control protocol specifies the interactions between the several functional elements that exist between the GPIB functions and the device specific functions, as shown in Figure 5.3.2. It specifies how messages are to be exchanged between device and controller. For example, it specifies exactly how a device shall handle program- and response messages that are received from and returned to a controller. This protocol introduces the idea of commands and queries; queries are program messages that require the device to send a response. When the controller does not read this response, the device will generate a Query Error. On the other hand, commands will not cause the device to generate a response. When the controller yet tries to read a response, the device will also generate a Query Error.

The Message Exchange Control protocol deals also with the order of execution of program messages. It defines how to respond on the occurrence of Command Errors, Query Errors, Execution Errors and Device Specific errors. Basically, the protocol puts the demand upon the device to report any violation of the IEEE 488.2 rules to the controller, even when it is the controller that infringes these rules.

5.3.2 Interface capabilities

Your programmable power supply has the following IEEE interface capabilities:

- SH1 : Complete Source Handshaking.
- AH1 : Complete Acceptor Handshaking.
- T5 : Basic Talker + serial polling + Talk only + unaddress if 'My Listen Address'.
- L3 : Basic Listener + Listen only + unaddress if 'My Talker Address'.
- SR1 : Complete Service Requesting.
- RL1 : Complete Remote / Local switching.
- PP0 : No parallel polling.
- DC1 : Complete Device Clearing.
- DT1 : Complete Device Triggering.
- C0 : No system Controller.
- E2 : Three-state drivers.

When the **REM** text (remote) is displayed, the power supply is in the remote state. When the **SRQ** text is displayed, the power supply is requesting for service by the controller, for instance to report a programming error.

5.3.3 Program and response messages

The communication between the system controller and the SCPI instruments, connected to the GPIB, takes place through Program and Response Messages. A Program Message is a sequence of one or more commands and/or queries, sent from the controller to an instrument. Conversely, a Response Message is the data from the instrument to the controller.

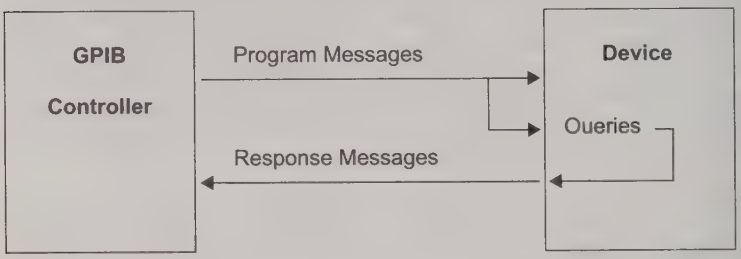


Figure 5.3.3 Program and Response messages

The GPIB controller instructs the device by program messages. The device will only send responses, when explicitly requested to do so, namely when the controller sends a so-called Query. Queries are recognized by the question mark at the end of the header, for example: *IDN? (requests the instrument identity data).

SYNTAX AND STYLE

Syntax of Program Messages

A command or query is called a program message unit. Such a program message unit consists of a header followed by one or more parameters, as the following syntax flow diagram shows.

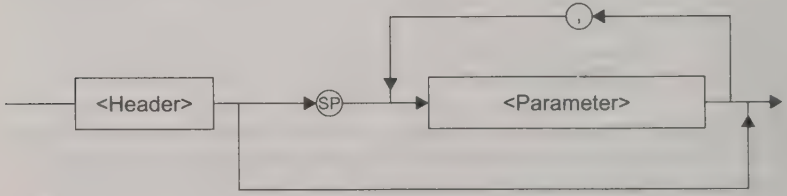


Figure 5.3.4 Syntax of a Program Message Unit

One or more program message units (commands) may be sent within a simple program message, as shown in figure 5.3.5.

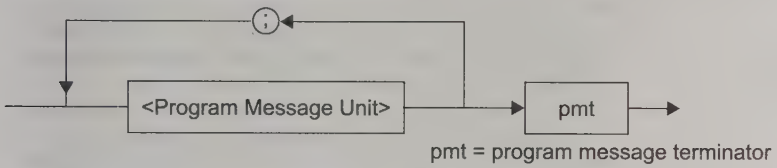


Figure 5.3.5 Syntax of a terminated Program Message

The pmt (program message terminator) must be one of the following codes:

- NL^END This is <new line> code sent concurrently with the END message on the GPIB.
- NL This is the <new line> code.
- <dab>^END This is the END message sent concurrently with the last data byte.

Notes: NL is the same as the ASCII LF (<line feed> = ASCII 10 decimal).
The END message is sent via the EOI-line of the GPIB.
The ^ character stands for 'concurrent with'.

Most controller programming languages send these terminators automatically, but allow changing it. So take care that the terminator is one of the above ones.

Example of a terminated program message:

:INPut:IMPedance 1E6;:SENSe: VOLTage:RANGe 200 NL^END

| program message unit | program message unit | terminator

This program message consists of two message units. Message units are separated by the message unit separator semicolon.

Basically there are two types of commands:

- SCPI commands SCPI command headers may consist of several keywords (mnemonics), separated by the colon character (:).
- Common commands The common command header starts with the asterisk character (*), for example *RST.

Each keyword in a SCPI command header, represents a node in the so- called SCPI command tree. The leftmost keyword (INPut in the previous example) is the root node, representing the highest hierarchical level in the command tree. Subsequent keywords represent subnodes under the root node. This subject is handled in more detail in the part **"COMMAND TREE AND COMMAND TABLE"**.

Long and short form

Mnemonics in SCPI program messages may be sent in either short or long form. The long and short form of the mnemonics obey mainly the following rules:

- The long form is the full word but maximum 12 characters. For example INITIATE
- The short form is the first four characters of the long form. Example: INIT
  Exception:
  - When the fourth character is a vowel and the four characters don't form the long form, then the short form is only the first three characters.
    Example: long form SWEEP, short form SWE
    But when the long form is FREE, then the short form also is FREE, because the short from is also the full word.

Example:

The syntax of a command is specified as follows:

:INSTrument:NSELect <numeric value>

where INST and NSEL specify the short form and
INSTrument and NSELect specify the long form
However, INSTRU or NSELE are not allowed and cause a command error.

Forgiving listening

In program messages either long or short form may be used in upper or lower case. Even a mix of upper and lower case is allowed. There is no semantic difference between upper and lower case in program messages. This instrument behaviour is called forgiving listening.

For example, an application program may cause the following literals to be sent over the bus:

:iNsT:NsEl 3	Short form used in a mix of upper and lower case.
:Instrument:Nsel 3	Long and short form used in a mix of upper and lower case.

Notation habit

To clarify the difference between short and long form, the short form in a syntax specification is shown in upper case and the remaining part of the long form in lower case characters. Notice however, that this does not specify the use of upper and lower case characters in the message that is actually sent. Bear in mind that upper and lower case, as used in syntax specifications, is only a notation habit to facilitate distinction between long and short form.

Syntax of Response Messages

The response of a SCPI instrument to a query (response message unit) consists of one or more parameters (data elements), as the following syntax diagram shows. There is no header returned.

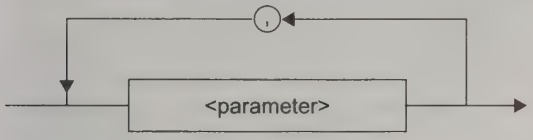


Figure 5.3.6 Syntax of a Response Message Unit

If there are multiple queries in the associated program message, the multiple response message units are grouped together in a response message, according to the following syntax:

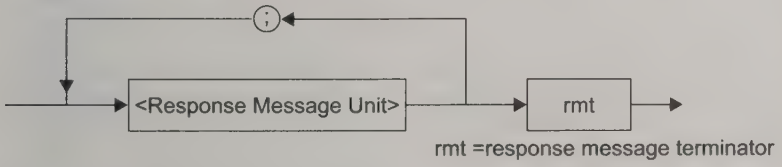


Figure 5.3.7 Syntax of a terminated response message

The response message terminator (rmt) is NL^END, where

NL^END Is <new line> code (equal to <line feed> code = ASCII 10 decimal) sent concurrently with the END message. The END message is sent by asserting the EOI-line of the GPIB bus.

Responses: A SCPI instrument will send its response data always in short form and in capitals.

Example: An instrument is programmed with the following command:
:AM:SOURce EXTernal
Subsequently the following query is sent to the instrument:
:AM:SOURce?
The instrument will return:
EXT response in short form and in capitals

COMMAND TREE AND COMMAND TABLE

Command Trees and Command Tables are common means to document a SCPI instrument's command set in Operation Manuals. The keyword (mnemonic) on the root level of the command tree is the name of the so-called subsystem. The following example illustrates the Command Tree in relation to the Command Table of the SENSE subsystem.

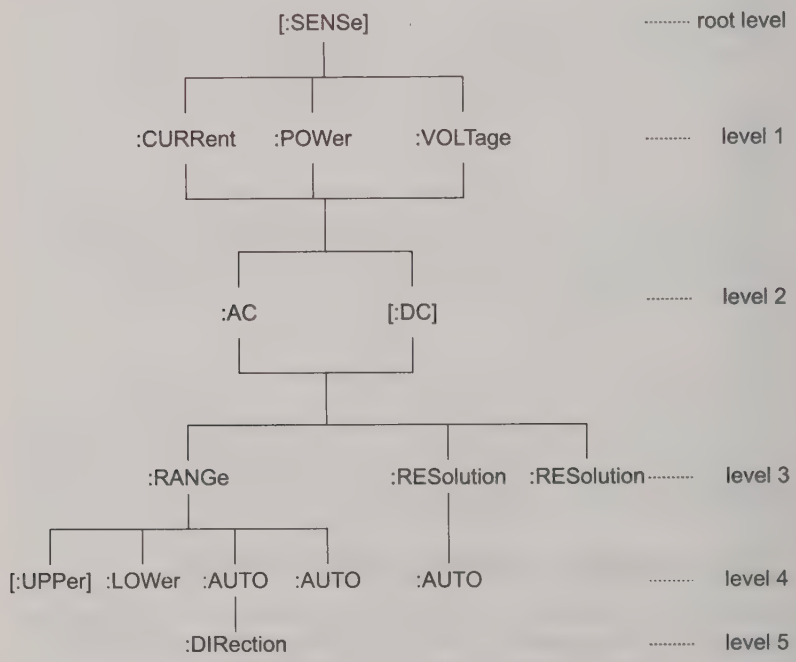


Figure 5.3.8 Example of the SENSe subsystem Command Tree (simplified)

Command (I means or)	Parameter Form	Description of values
[:SENSe]		
:CURRent		
|:POWer		
|:VOLTage		
[:DC]		
|:AC		device dependent values
:RANGe		
[:UPPer]	<numeric_value>	
:LOWer	<numeric_value>	
:AUTO	<boolean>|ONCE	
:DIRection	UP|DOWN|EITHer	
:RESolution	<numeric_value>	
:AUTO	<Boolean|ONCE	

Figure 5.3.9 Example of a SENSe Subsystem Command Table (simplified)

The keywords placed in square brackets are so-called optional nodes. This means that they may be omitted in a program message.

Example:
:SENSe:VOLTage:DC:RANGe:UPPer 5 is the same as :VOLTage:RANGe 5

Traversing the command tree

The command tree shows the paths to be used for the syntax of certain commands. The syntax of a single terminated command begins from the root level downwards to the 'leaf-nodes' of the command tree. Example:

:SENSe:VOLTage:DC:RANGe:UPPer

where SENSe is the root node and UPPer the leaf-node.

Leaf-nodes are the last keywords in the command header. A command may or may not have parameters. Note that the command tree shows up to the leaf-nodes but does not show parameters, whereas the command table also shows the parameters.
Each colon in the command header moves the current path down one level from the root in the command tree. The command tree shows possible paths, in which the last node is the leaf-node. For the proper understanding of command trees and command tables in relation to the command syntax, the following rules are valid:

1. For the first command in a new program message, always give the full header (path) from the root.
2. For subsequent commands within the same program message:
   - the complete command header shall be repeated from the root,

   or - the header path may be omitted and the leaf-node sent only. However, this is only allowed if the header path of this command is the same as that of the previous command.

Command header = Header path + leaf-node

For example:	:VOLTage:DC:RANGe:UPPer	is the command header,
where	:VOLTage:DC:RANGe	is the header path,
and	:UPPer	is the leaf-node.

This means, :VOLTage:DC:RANGe:UPPer 3;LOWer 0.5
is a valid program message, because LOWer is also a leaf-node under the header path VOLTage:DC:RANGe

3. Once the pmt (program message terminator) is sent, the first command in a new program message shall start from the root.

PARAMETERS

Numeric data

Numeric values are used to represent decimal data throughout this document. Numeric values may be in implicit or explicit decimal point notation form. They may also contain exponential (base 10) notation. These numerals are often represented as NRf (NR = NumeRic, f = flexible) format. Further, with <numeric_value>, several keywords as special forms of numeric data, such as MINimum, MAXimum, DEFault, STEP, UP, DOWN, NAN (Not A Number), INFinity, NINF (Negative INFinity) can exist. The keywords, which are allowed within a particular command, are always explicitly specified.

DEFault	This keyword is to indicate that the value of the current parameter will be defaulted: the value which is used if no value is specified. The device can take a specific value or may leave the setting unchanged, dependent upon the device's choice.
MINimum	This keyword will provide the minimum value for a parameter.
MAXimum	This keyword will provide the maximum value for a parameter.

MINimum and MAXimum are always allowed as data element in commands. where the parameter is a numeric value, and are always queryable.

Example: :SENSe:VOLTage:RANGe? MAXimum
This query returns the maximum range value.

Suffixes of numeric data

Suffixes are used to express a unit or multiplier being associated with the decimal numeric data.

Example: :SENSe:VOLTage:RANGe? 100mV
where mV is the suffix for the numeric value 100.
Notice that mV may also be sent as MV or mv.

Response messages do not have suffixes. The returned value is to be associated with standard units, as V, A, Hz etcetera, unless a default unit is explicitly specified by a FORMat command.

Booleans

A boolean is used to specify a single binary condition which is either true or false.

Boolean parameters These can be one of the following:

ON or 1 Means condition true.
OFF or 0 Means condition false.

Example: :INST:STAT ON
or :INST:STAT 1
This sets the power supply in OPERATE mode..
But :INST:STAT? will return 1 or 0; never ON or OFF.

Expression data

Expression program data are enclosed in parenthesis (). Two possibilities of expression data are:

- <numeric expression data>
- <channel list>

An example of <numeric expression data> is:

(215MOD16) this provides the remainder of 215 divided by 16.

An example of <channel list> is:

(@1,3,4:20) this specifies the channels 1, 3 and 4 through 20.

Other data types

Other data types which can be used for parameters, are:

• String data	Always enclosed between double quotes, for example "This is a string".
• Character data	For this data type, the same rules are valid as for the mnemonics being used in command headers. For example: POSitive, NEGative, EITHer etcetera.
• Non-decimal data	As e.g. #H3A for hexadecimal data.
• Block data	Used to transfer any 8-bit coded data. This data starts with a preamble that contains information about the length of the parameter.

5.3.4 Instrument model

The possibility to measure signals at different levels of complexity is an important feature of a SCPI instrument.
In order to properly define the various control commands, SCPI makes use of a generalized model of a programmable instrument.

This so-called instrument model is depicted in figure 5.3.10.

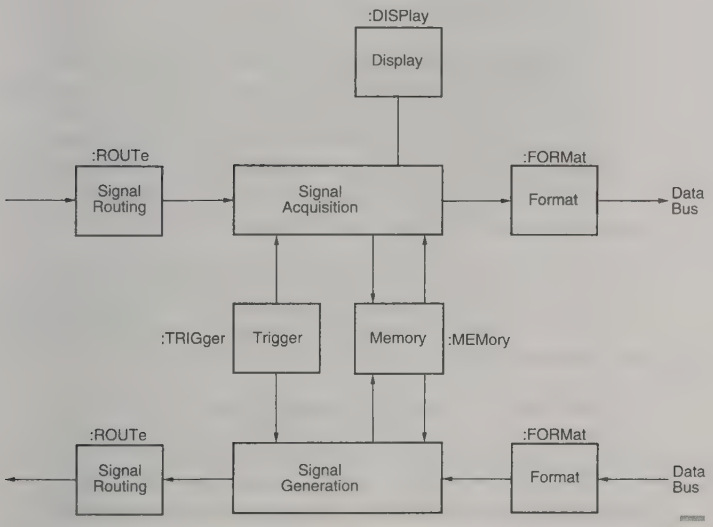


Figure 5.3.10 Instrument model

The instrument model shows the classification of the functionality of the instrument. The functionality is divided in different blocks. The hierarchical command structure of SCPI is based upon this partition.

Control of instrument functions

To be able to program the functions of an instrument it is necessary to have knowledge and understanding of the above instrument model. The SCPI commands are divided in groups, the so-called subsystems. The control of the functionality of a block is linked to the commands of the related subsystem.

For instance, the main task of a SENSe instrument is data acquisition. The SCPI instrument model contains three subsystems for signal acquisition: INPut, SENSe and CALCulate, as figure 5.3.11 shows.

Figure 5.3.11 Signal Acquisition

ROUTe — Signal Routing is performed by the ROUTe subsystem. It is basically a switch functionality that routes the signals applied from the instrument's input ports to the INPut block (if it is a SENSe instrument; see figure 5.3.11) or from the instrument's OUTPut block to its output ports (if it is a SOURce instrument). For switch instruments, the ROUTe subsystem directly controls the connection from signal port to signal port.

DISPlay — This subsystem contains the functionality associated with the presentation of data. Presentation can be in any form like textual or graphical. The data being presented may be measurement data, user interactions, status data, etcetera.

FORMat — This subsystem deals with converting between data formats. Especially on data for transferring over the GPIB.

TRIGger — The TRIGger subsystem controls the data acquisition (or data generation) by synchronizing the device actions with internal or external events.

SOURce — This subsystem generates a signal based on specified characteristics and/or supplied data.

SENSe — This subsystem contains the functions that perform the real data acquisition. Its purpose is to convert the signal into internal data.

CALCulate — Performs the post-processing functions that are needed on the acquired data. It is the logical element between the SENSe subsystem and data output function like the DISPlay and FORMat subsystem.

INPut This subsystem controls the characteristics of a sensor's input port, such as IMPedance and GAIN. Typically the signal conditioning before the signal is converted in the SENSe block.

OUTPut This subsystem controls the characteristics of a source's output port, such as ATTenuation and COUPling.

Major categories of instruments

From the instrument model, three major categories of functions can be derived:

Function	Instrument type	Examples
Signal acquisition	sense instrument	voltmeter, oscilloscope, counter
Signal generation	source instrument	pulse generator, power supply
Signal routing	switch instrument	scanners, (de-)multiplexers

An instrument may implement a combination of the above functions.

Besides the major functions (subsystems), there are several other subsystems in the instrument model, such as the following:

SYSTem The SYSTem subsystem includes the more general functions of the instrument which are not directly related to instrument performance, such as TIME and DATE settings.

MEMory The MEMory subsystem includes the functions, which manage instrument memory. This excludes the memory used for mass storage, which is included in the MMEMory subsystem.

MMEMory The Mass MEMory subsystem includes the mass memory device commands to provide mass storage capabilities for instruments.

INSTrument An instrument may support multiple logical instruments. For example, a dual scanner is considered as two logical instruments. The INSTrument subsystem provides a mechanism to identify and select particular logical instruments.

STATus This subsystem controls the SCPI status reporting system, such as reading status registers but also programming transition filters, which affect event detection.

The commands needed to control a functionality, which belongs to a particular subsystem, always begin with the name of that subsystem. For instance, the attenuator of an input amplifier, is a functionality that is to be associated with the INPut subsystem. The command that controls this attenuator, will have :INPut as leading (root) node in its header. In this case, the command is:

:INPut:ATTenuation <numeric_value>

MEASure function

Besides the subsystems of the instrument model, which are intended to control the instrument functionality, SCPI offers signal oriented capabilities to obtain measurement results. This group of MEASure functions have different levels of compatibility and flexibility. The parameters associated with commands from the MEASure group, relate to and are expressed in terms of the signal to be measured. This means that the MEASure? functions provide best compatibility between instruments, because no knowledge of the instrument is required.

- MEASure?
  This is the most simple to use, but does not offer much flexibility.
  The MEASure? command configures the instrument for optimal settings, starts the data acquisition and returns the result.

  Example: :MEASure:VOLT:AC?

  This will execute an AC-voltage measurement and the result will be sent to the controller. The instrument itself will select an optimal setting for this purpose and will carry out the required measurement as "good" as possible. Moreover it will start automatically the measurement.

  Parameters may be added to give further details on the signal to be measured, for example:
  :MEASure:VOLTage:AC 20,0.001 where 20 is the expected signal value and 0.001 is the required resolution.

  Also the channel numbers can be specified, for example:
  :MEASure:VOLTage:AC (@2,5) or
  :MEASure:VOLTage:AC 20,0.001,(@2,5) is possible.

- CONFigure
  READ?
  The CONFigure command causes the instrument to choose an optimal setting for the specified measurement. CONFigure may cause any device setting to change. READ? starts the acquisition and returns the result.

This sequence performs the same as the MEASure command, but now it is possible to insert commands in between CONFigure and READ? to perform the setting of a particular function (so called fine tuning), e.g. to set an input attenuator at a required value.

Example:

:CONFigure:VOLTage:AC 20,0.001	0.001 Is the required resolution, 20 is the expected signal value.
:INPut:IMPedance 1E6	Sets input impedance to 1 MOhm.
:READ?	Starts measurement and returns the result.

- CONFigure
  INITiate
  FETCh?
  The READ? command can be divided further into the INITiate command, which starts the measurement, and the FETCh? command, which requests the instrument to return the measuring results to the controller. Herewith is it possible to obtain different characteristics of the measured signal, with successive FETCh? commands.

Example:

:CONFigure:VOLT:AC 20,0.001	0.001 Is the required resolution, 20 is the expected signal value.
:INPut:IMPedance 1E6	Sets input impedance to 1 MOhm.
:INITiate	Starts measurement.
:FETCh:VOLTage:AC?	Returns the AC-component of the signal measured.
:FETCh:VOLT:PERiod?	Returns the period of the signal measured.

Overview

<table>
<tr><td rowspan="2">MEASure?</td><td>CONFigure</td><td>CONFigure</td></tr>
<tr><td rowspan="2">READ?</td><td>INITiate</td></tr>
<tr><td>FETCh?</td></tr>
<tr><td>Simple to use, few additional possibilities.</td><td>Somewhat more difficult, but some extra possibilities.</td><td>Rather difficult to use, but many extra features</td></tr>
</table>

5.3.5 Status reporting system

Structure of the Status System

The status structure of an instrument is used to reflect the current instrument condition and to report all kind of events that happened. The status is ultimately reported in the instrument's Status Byte Register.
The status structure consists of Register Model and Queue Model structures. The Standard Event Status is an example of a Register Model structure; the Output Queue an example of a Queue Model structure. All Status Models, registers and queues, are summarized in the Status Byte Register. From the Status Byte Register it is always possible to trace back to the event that caused the corresponding summary bit to be set.

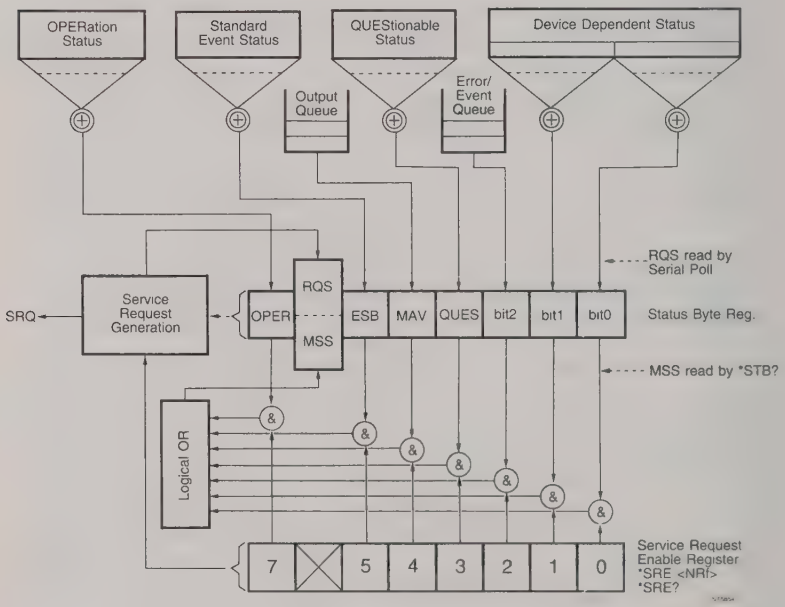


Figure 5.3.12 General model of the status structure

Characteristics of the different types of status data

OPERation status	This contains the conditions which are part of the instrument's normal operation.
QUEStionable status	This contains the bits which give an indication of the quality of various aspects of the signal.
Standard Event status	This contains the standard events. The Standard Event Status system is accessible through common commands.
Output Queue	The non-empty status of the Output Queue is reported in the MAV-bit in the Status Byte Register.
Error/Event Queue	The non-empty status of the Error/Event Queue is reported in bit2 in the Status Byte Register.
Device-Dependent status	This contains the device dependent status data (the device specific status data that is not reported through the other status structures).

- For each status structure there is an event register, that reflects the events itself, and an enable register. The enable register selects which events are summarized into the Status Byte Register.
- The Status Byte Register can be read by either Serial Poll or by the *STB? query. The Status Byte Register is cleared only by clearing its overlaying structures.
- The Service Request Enable Register allows to select particular bits from the Status Byte to generate a Service Request (SRQ) on the GPIB.

5.3.6 Error and event reporting

An instrument will place detected errors and/or events in its Error/Event Queue. This queue is a FIFO (First-In-First-Out) buffer. The first error will come out first, the last error only, when the queue is read.

How can the presence of errors in the queue be detected.

Bit 2 in the Status Byte Register, if set true, indicates that the instrument detected errors. It is also possible to enable this bit for Service Request on the GPIB. This can then interrupt the GPIB controller program on occurrence of an error.

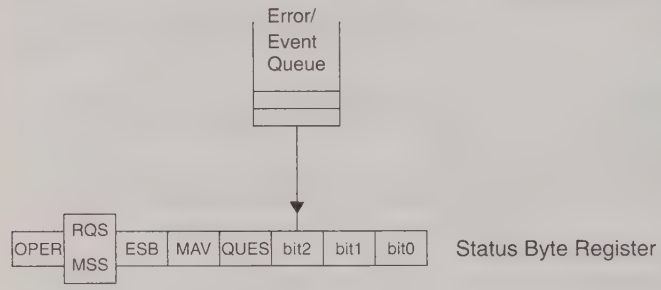


Figure 5.3.13 Error summary in the Status Byte Register

How to read the Error/Event Queue.

This is done with the :SYSTem:ERRor? query, or its alias STATus:QUEue[:NEXT]? query.

Example:

Send → :SYSTem:ERRor?
Read ← -100, "Command Error"

The query returns the error number followed by the error description.

If more than one error occurred, the query will return the error, which was first placed in the queue. The error read is removed from the queue and the next error may be read by repeating the query. When all errors are read, the queue is empty and the :SYSTem:ERRor? query will return:

0, "No error"

When errors occur while the user does not read these errors, the Error Queue may overflow. Then the last error in the queue will be overwritten with error:

-350, "Queue overflow"

Subsequent errors will be discarded.

Standardized Error numbers:

There are four groups of standardized errors, which are reported in the Standard Event Status and in the Error/Event Queue, namely:

Error class	Range of Error numbers	Standard Event Register
Command Error	-100 to -199	bit 5 CME
Execution Error	-200 to -299	bit 4 EXE
Device-Specific Error	-300 to -399	bit 3 DDE
Query Error	-400 to -499	bit 2 QYE

Note: Negative error numbers are defined by the SCPI standard; positive error numbers are device dependent. An error value of zero, indicates that no number (or event) has occurred.

Command Error

This error indicates that the instrument detected a syntax error.

Execution Error

This error indicates that a valid program message is received that can not be executed due to some device specific conditions.

Device-Specific Error

This error indicates that the instrument could not properly complete some device specific operations.

Query Error

This error will occur when the Message Exchange Protocol is violated. For example, when a query is sent to the instrument and subsequently a new command is sent without first having read the response data from the previous query. Also, trying to read data from the instrument without first sending a query to the instrument, will cause this error.

5.3.7 Programmable functions

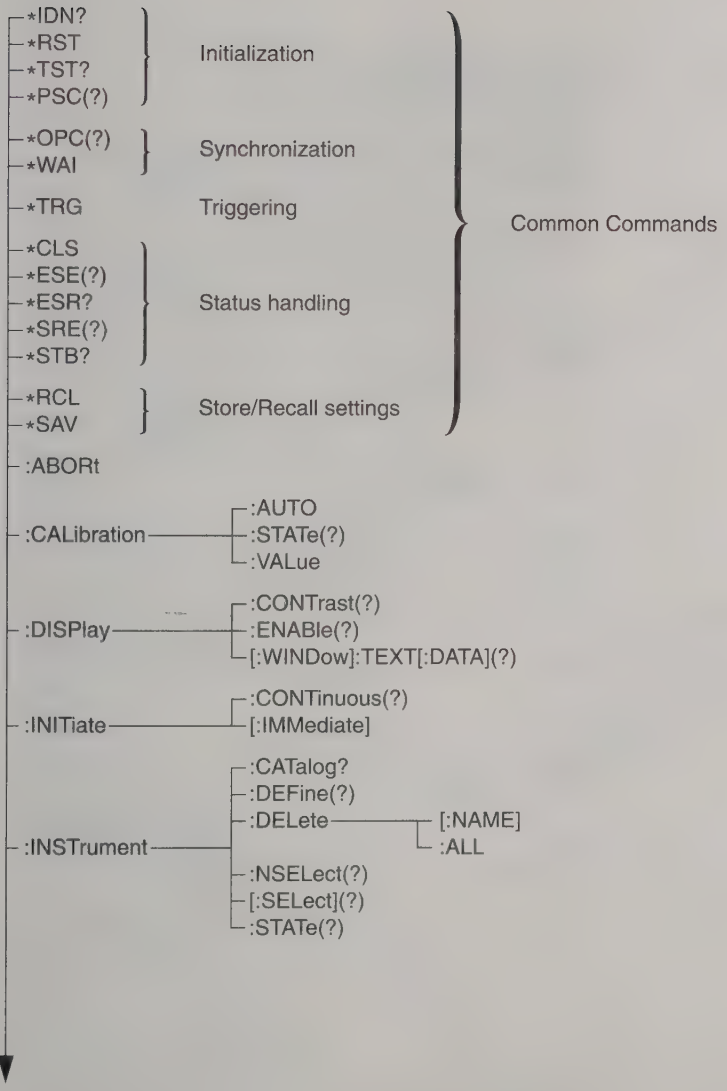
Remote operation of your power supply is done through programming commands and queries via the GPIB interface. The commands and queries have been divided into functional subsystem groups. This makes the functional programming of your power supply very easy. The following groups have been defined:

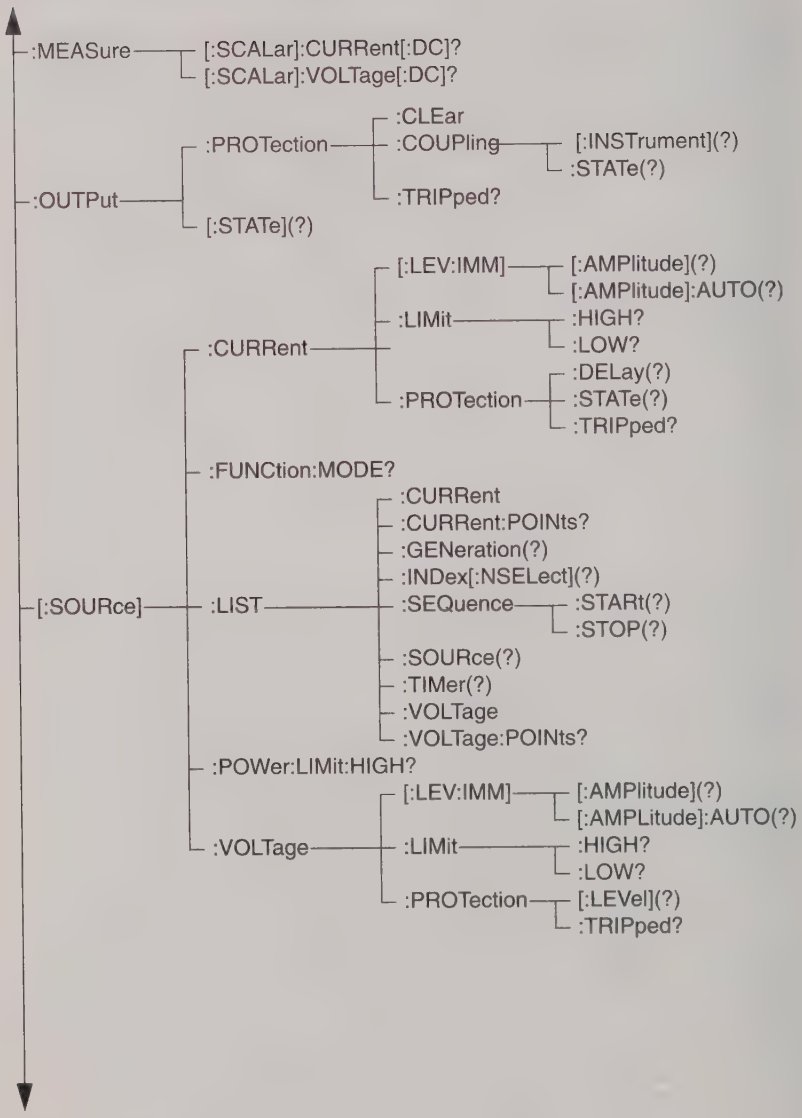
- Common IEEE 488.2 : Common IEEE (GPIB) functions
- Abort step function : ABORt subsystem
- Calibration : CALibration subsystem
- Display handling : DISPlay subsystem
- Initiate step function : INITiate subsystem
- Instrument handling : INSTrument subsystem
- Measuring : MEASure subsystem
- Output handling : OUTPut subsystem
- Source settings : SOURce subsystem
- Status handling : STATus subsystem
- System handling : SYSTem subsystem
- Testing : TEST subsystem

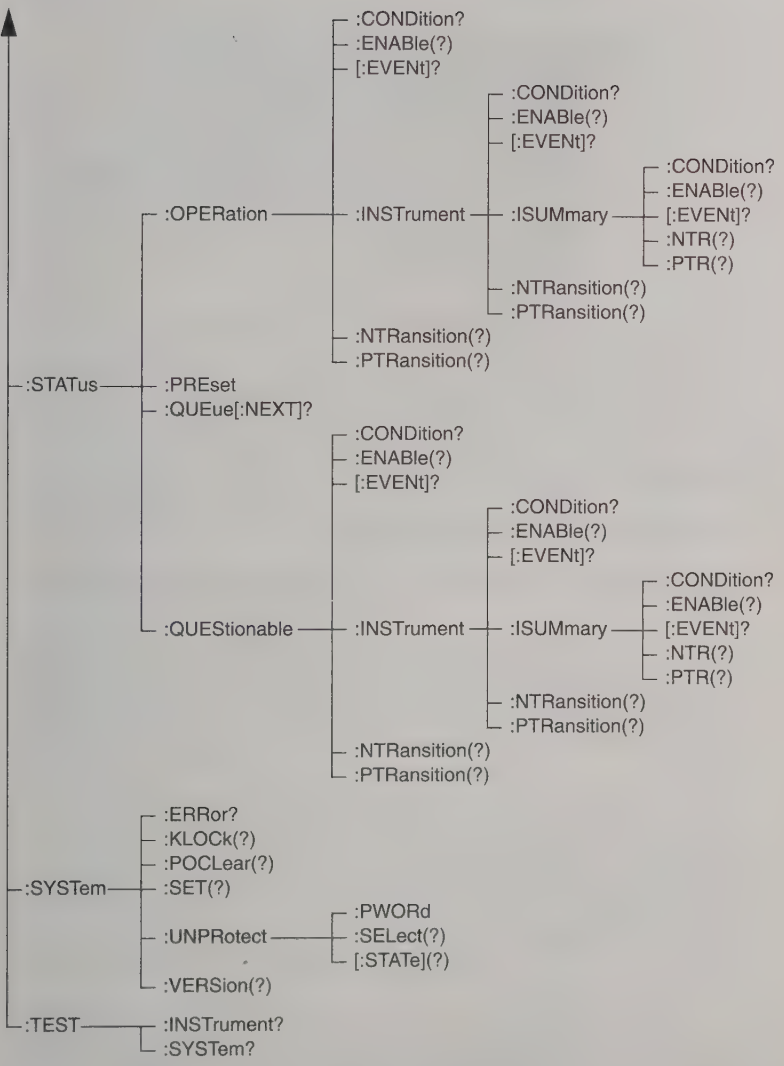
The following schemes show the structure of the common and subsystem commands and queries:

Rules:
- Common commands begin with an asterix "*".
- Queries end with a question mark "?".
- UPPERCASE specifies the part which is mandatory in the syntax of commands and queries.
- UPPERCASE in the syntax of the command/queries does NOT mean that uppercase is obligatory; lowercase may used as well.
- A command header node between square brackets specifies the default, and may be omitted.
- Commands that also have a query form, are combined in the following command tree. The question mark "?", to be appended for the query is placed between parentheses.
  :OUTPut(?) means command :OUTPut and query :OUTPut?

For more details, please refer to section 5.3.3 Program and response messages.


*IDN?
*RST
*TST?
*PSC(?)
Initialization
*OPC(?)
*WAI
Synchronization
*TRG
Triggering
*CLS
*ESE(?)
*ESR?
*SRE(?)
*STB?
Status handling
*RCL
*SAV
Store/Recall settings
Common Commands
:ABORt
:CALibration
:AUTO
:STATe(?)
:VALue
:DISPlay
:CONTrast(?)
:ENABle(?)
[:WINDow]:TEXT[:DATA](?)
:INITiate
:CONTinuous(?)
[:IMMediate]
:INSTrument
:CATalog?
:DEFine(?)
:DELete
[:NAME]
:ALL
:NSELect(?)
[:SELect](?)
:STATe(?)


:MEASure
[:SCALar]:CURRent[:DC]?
[:SCALar]:VOLTage[:DC]?
:OUTPut
:PROTection
:CLEar
:COUPling
[:INSTrument](?)
:STATe(?)
:TRIPped?
[:STATe](?)
[:SOURce]
:CURRent
[:LEV:IMM]
[:AMPlitude](?)
[:AMPlitude]:AUTO(?)
:LIMit
:HIGH?
:LOW?
:PROTection
:DELay(?)
:STATe(?)
:TRIPped?
:FUNCtion:MODE?
:LIST
:CURRent
:CURRent:POINts?
:GENeration(?)
:INDex[:NSELect](?)
:SEQuence
:STARt(?)
:STOP(?)
:SOURce(?)
:TIMer(?)
:VOLTage
:VOLTage:POINts?
:POWer:LIMit:HIGH?
:VOLTage
[:LEV:IMM]
[:AMPlitude](?)
[:AMPLitude]:AUTO(?)
:LIMit
:HIGH?
:LOW?
:PROTection
[:LEVel](?)
:TRIPped?


:STATus
:OPERation
:CONDition?
:ENABle(?)
[:EVENt]?
:INSTrument
:CONDition?
:ENABle(?)
[:EVENt]?
:ISUMmary
:CONDition?
:ENABle(?)
[:EVENt]?
:NTR(?)
:PTR(?)
:NTRansition(?)
:PTRansition(?)
:NTRansition(?)
:PTRansition(?)
:PREset
:QUEue[:NEXT]?
:QUEStionable
:CONDition?
:ENABle(?)
[:EVENt]?
:INSTrument
:CONDition?
:ENABle(?)
[:EVENt]?
:ISUMmary
:CONDition?
:ENABle(?)
[:EVENt]?
:NTR(?)
:PTR(?)
:NTRansition(?)
:PTRansition(?)
:NTRansition(?)
:PTRansition(?)
:SYSTem
:ERRor?
:KLOCk(?)
:POCLear(?)
:SET(?)
:UNPRotect
:PWORd
:SELect(?)
[:STATe](?)
:VERSion(?)
:TEST
:INSTrument?
:SYSTem?

5.4 Operating features

Your programmable power supply is equipped with a GPIB interface, which conforms to the IEEE-488.2 standard and the SCPI protocol (Standard Commands for Programmable Instruments). Via the GPIB the power supply can be programmed to operate in a remotely controlled instrumentation system.

You can use each output channel of the power supply as a constant voltage source (CV mode) or as a constant current source (CC mode). There are two instrument types available:

- single output channel power supply
- dual output channel power supply

Two versions of power rating for the output channels are available:

- 60V / 2A / 120W
- 120V / 1A / 120W

The operating structure and operating principles are identical for each instrument type and for each output channel.

The following features have been implemented in each power supply:

- Power on self test and diagnostics routines.

- Readback capability of the measured voltage and current of each output channel.

- Each output channel offers the ability to sense locally or remotely. For remote sensing, the sense terminals (+S and -S) must be connected to the load instead of the +V and -V output terminals; then the programmed voltage (V_{set}) is guaranteed to be across the load, in spite of the voltage drop in the wires to the load.

- A nonvolatile memory (battery backed-up). This enables you to:
  - store and recall voltage and current settings of all output channels (refer to section 5.5.4 "Store/Recall function")
  - save and recall the frontpanel settings (refer to the common commands *SAV and *RCL).

  In this way stored settings can be recalled, even after a long period of power off.

- Extended STEP possibilities, i.e., the capability to step sequentially through a number of predefined voltage and current settings. This can be done: - Manually using the STEP key.
  - Automatically at predefined intervals (internal timer)
  - Externally - by a STEP line trigger via the trigger bus
    - by a trigger via the GPIB interface

  With this feature, test patterns can be generated and ramp functions can be simulated. The following scheme shows in which operating modes the STEP capabilities can be used:

TRIGGER SOURCE	LOCAL OPERATION	REMOTE OPERATION
MANUAL	STEP key	Not possible
AUTOMATIC	AUX key	:SOURCE:LIST:... commands :INIT / :ABORT command
EXTERNAL-STEP line	STEP line	Trigger STEP line trigger
EXTERNAL-GPIB	not applicable	*TRG / GET command

- Closed-case calibration, i.e., your power supply can be calibrated without removing the cover or even without removing the instrument from your system cabinet. This feature allows you to calibrate your power supply at its normal operating temperature. The recommended calibration interval is one year. Refer to section 7.3.3 "Calibration" for complete calibration details.

- Protection circuitry for safe operation of your power supply:
  - protection against OVERTEMPERATURE
  - by reporting an UNREGULATED output channel situation
  - by reporting conflicts in parameter settings
  - by reporting erroneous situations during operation

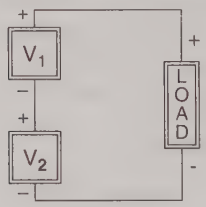
- Protection circuitry to protect a connected load:
  - against OVERVOLTAGE on each output channel
  - against OVERCURRENT on each output channel
  - detection of sense break, or exceeding the sense capability on each output channel
  - by means of the possibility to couple the voltage and current setting of the same output channel
  - by means of the possibility to couple the protection mechanisms of different output channels of the same power supply

To increase the total output power, connect an output channel to another output channel of the same voltage and current ratings. The connection can be made in series or in parallel. The output channels to be connected can be from the same power supply or from different power supplies; however, the feature to couple

protection mechanisms is only possible for output channels within the same power supply.

The following illustrations show the possible connections.

- SERIES connection to increase the total output voltage capability:

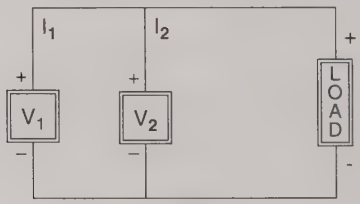


$V_{load} = V_1 + V_2$
$I_{load} = V_{load} / R_{load}$
$P_{load} = V_{load} \times I_{load}$

WARNING: To guarantee the safe use of the power supply, the total maximum voltage at each terminal may not exceed 240V with respect to ground.

Examples:
- 2x 60V/2A = 120V/2A : maximum power = 240W
- 2x 120V/1A= 240V/1A : maximum power = 240W

- PARALLEL connection to increase the total output current capability:



$I_{load} = I_1 + I_2$
$V_{load} = I_{load} \times R_{load}$
$P_{load} = I_{load} \times V_{load}$

Examples:
- 2x 60V/2A = 60V/4A : maximum power = 240W
- 2x 120V/1 = 120V/2A : maximum power = 240W

CAUTION: Only output channels with equivalent voltage and current ratings may be connected in series or in parallel!

5.5 How to use the operating features

This section contains information about how to use the features of your power supply, such as:

- How to deal with output channel-specific ratings and characteristics.
- Local and remote sensing.
- Using an output channel as constant voltage or constant current source.
- Using the memory functions:
  - Store/recall voltage/current settings.
  - Step manually through voltage/current settings.
  - Step automatically through voltage/current settings.

5.5.1 Output channel characteristics

The following characteristic shows the work area of the output parameters. The linear system power supplies PM2831 and PM2832 can source as well as sink currents. There is, however, only one setting for current. When, namely, the power supply is used as a load, the value of the sink current will always track the positive setting.

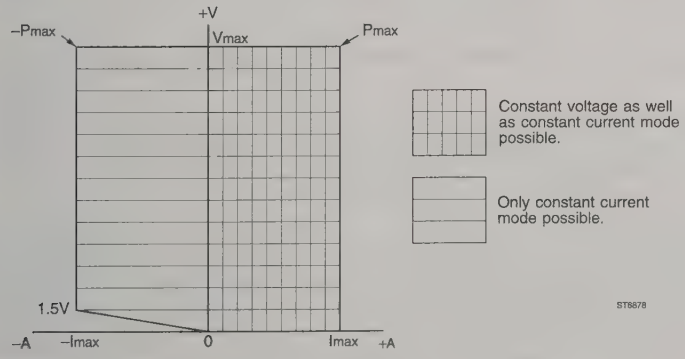


Figure 5.5.1 Output channel characteristics

This characteristic shows that the power supply will output maximum power (only) at V_{max} @ I_{max} and it will absorb maximum power at V_{max} @ $-I_{max}$.
Overcurrent protection, if enabled, will also work for sink currents that exceed I_{set}.
Also overvoltage protection will work for voltages applied from an external source, if the voltage from this source exceeds the overvoltage protection level.

Current sinking characteristics

The following figure gives an example that shows the sinking characteristics of the power supply. The power supply is used as a constant current load for an external source, where the sinking capability of the power supply is demonstrated. Overvoltage protection is set to maximum level and overcurrent protection is disabled.

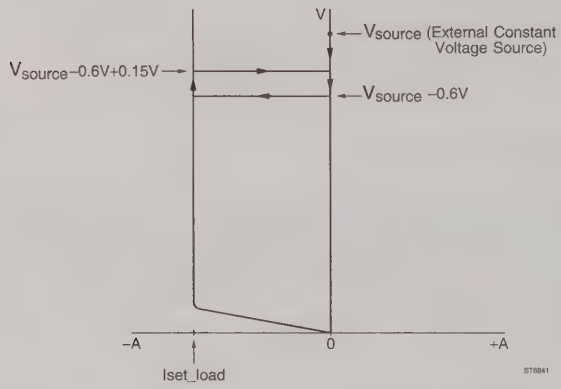


Figure 5.5.2 Current sinking characteristics

The power supply and the external source (this may be another power supply) are set to the same output voltage: V_{source}. There is no current flow yet.
The current settings are: $I_{set_source} > I_{set_load}$.
The voltage setting of the load is gradually decreased by means of the -V+ key. The change of the actual voltage setting is not visable on the display, because it will show the constant voltage applied by the external source. But the voltage setting of the power supply can be made visable at any moment by pressing the V key. When the setting approaches V_{source} - 0.6V, the power supply switches to the constant current (CC) mode at the level of $-I_{set\ load}$. In this situation the negative current of the power supply tracks the programmed (positive) value I_{set_load}.
Now the voltage is raised by means of the -V+ key. When the setting approaches V_{source} - 0.6V + 0.15V, the power supply will exit constant current mode, and return to the constant voltage mode @ 0A.

5.5.2 Local and remote sensing

All models have the ability to sense the output voltage locally or remotely. The wires between an output channel and the connected load have a resistance, which causes a voltage drop. If the voltage drop is not acceptable, remote sensing must be applied (refer to section 5.5.2.2).

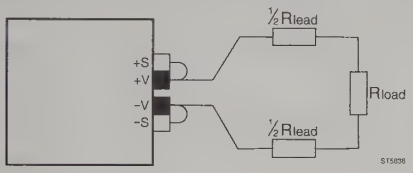


Figure 5.5.3 Voltage drop due to Wire Resistance R_{lead}.

The formula to calculate the voltage drop is $\mathbf{V_{drop}} = \mathbf{I_{load}} \times \mathbf{R_{lead}}$:

- $\mathbf{V_{drop}}$ = the total voltage drop of both wires
- $\mathbf{I_{load}}$ = the current through the load
- $\mathbf{R_{lead}}$ = the total resistance of both wires between the power supply and the load

In figures 5.5.4 and 5.5.5 the difference between a local and remote connection has been indicated.

CAUTION: You must set the power supply to the standby mode before making any changes in the output channel connections or you must disable the output channel (only possible for multiple output models).

All the models and their output channels have the same terminal block (see the diagram below). This means that all output channels have the local or remote sensing feature. The load is supplied with power (voltage and/or current) through the output terminals **-V** and **+ V**. The readback of the output voltage is done through the input terminals -S and + S.

5.5.2.1 Local sensing mode

Local sensing is used when the voltage accross the load need not to be compensatd for the voltage drop accross the load leads. This may be the case when the following conditions exist:

- Short wires between the output channel and the load ($R_{load} > R_{lead}$).
- Low current through the connected load.

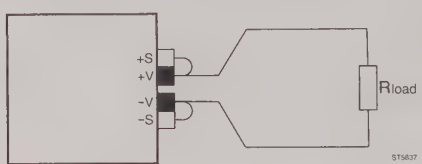


Figure 5.5.4 Connection of a Load in the Local Sense Mode

5.5.2.2 Remote sensing mode

Remote sensing is used if the voltage accross the load must exactly match the programmed value; remote sensing will namely compensate for the voltage drop accross the load leads. This mode will be useful when the following conditions exists:

- Long leads between the output channel and the load ($R_{load} \leq R_{lead}$).
- High current through the connected load.

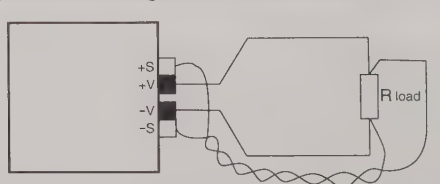
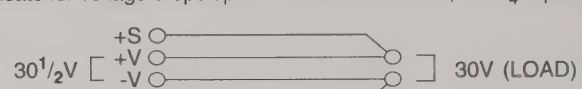


Figure 5.5.5 Connection of a Load in the Remote Sense Mode

Note that with remote sensing, the readback of the load voltage is monitored at the load terminals. When using the remote sensing mode, it is necessary to twist the sense wires to avoid disturbance and noise pick up in the sense input terminals, which might cause instability of the output. During remote sensing, the power supply can compensate for voltage drops up to a maximum of 0.5 V, i.e. $^1/_4$ V per wire.

Example:



5.5.3 Constant voltage or constant current source

Your power supply has been designed according to the automatic crossover principle. This means that each output channel will operate in the 'Constant Voltage' (CV) mode or in the 'Constant Current' CC mode, depending on:

- the programmed output voltage V_{set} and current I_{set}
- the resistance (impedance) of the load R_{load}, connected to the output channel

For a given V_{set} and I_{set}, an output channel is either:

in the CV mode if $\left[R_{load} > \frac{V_{set}}{I_{set}}\right]$ or in the CC mode if $\left[R_{load} < \frac{V_{set}}{I_{set}}\right]$.

In the CV mode the output is a constant voltage, so the current through the load depends on the load resistance (R_{load}).
In the CC mode the output is a constant current, so the voltage across the load depends on the load resistance (R_{load}).

The following picture shows when the output channel goes into the CV or into the CC mode of operation, when connected to a variable resistor R_{load}.

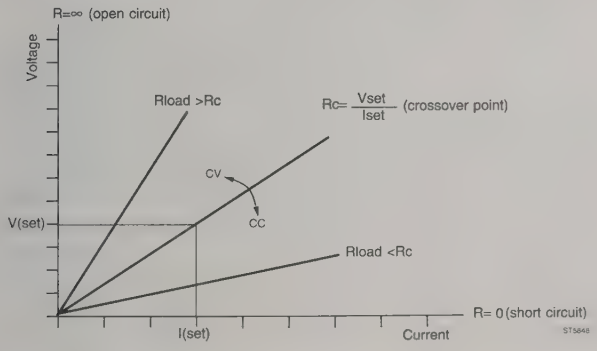


Figure 5.5.6 Power Output Crossover Point

If R_{load} increases ($R_{load} > R_c$), the output channel goes into the CV mode, reducing the current through the load.
If R_{load} decreases ($R_{load} < R_c$), the output channel goes into the CC mode, reducing the voltage across the load.

To protect the load against excessive currents, the maximum current I_{set} can be programmed, and the overcurrent protection can be enabled.
To protect the load against excessive voltages, the overvoltage protection level OVP_{set} can be programmed.

LIMITATIONS (also refer to figure 5.5.1)

The output power is limited by:

- the output specific maximum power P_{max}, according to the formulae: $I_{set} \times V_{set} <= P_{max}$

RESTRICTIONS (also refer to figure 5.5.1)

The output voltage is restricted by:

- the output specific maximum voltage, or
- the overvoltage protection level OVP_{set}

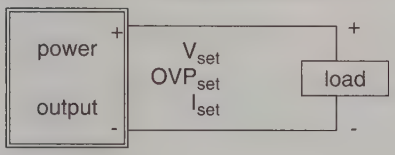
Note: When the output voltage exceeds the overvoltage protection level, both the output voltage and current are reduced to zero.

The output current is restricted by:

- the output specific maximum current, or
- the programmed maximum current level I_{set}

Note: If the overcurrent protection has been enabled and the output current exceeds the maximum current (I_{set}), the output voltage and current are reduced to zero.
If the overcurrent protection has been disabled, the output current will be kept at its maximum (I_{set}). The consequence is that the output voltage will not reach its programmed value (V_{set}), and the output channel will go into the CC mode.

Example for a variable load resistance:



V_{set} = Voltage programmed
I_{set} = Current programmed
R_{load} = 50 to 150Ω (variable)

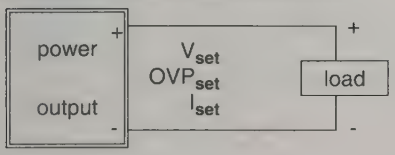
Required: The V_{set} and I_{set} parameter have been coupled for the selected output channel.

- I_{Set} = 0.5A Programmed current becomes 0.5A.
- V_{set} = 50V Programmed voltage becomes 50V.

The cross-over point resistance $R_c = V_{set} / I_{set} = 100\Omega$.

- If $R_{load} = 80\Omega$, then $R_{load} < R_c$, so the output channel is in the CC mode (refer to figure 5.5.6). This means that I_{load} = 0.5A and V_{load} becomes 0.5 x 80 = 40V.
- If R_{load} increases from 80Ω to 150Ω, then $R_{load} > R_c$, so the output channel goes into the CV mode (refer to figure 5.5.6). This means that V_{load} = 50V and I_{load} becomes 50 / 150 = 3.333A.
- If R_{load} decreases from 150Ω to 50Ω, then $R_{load} < R_c$, so the output channel goes into the CC mode (refer to figure 5.5.6). This means that I_{load} = 1A and V_{load} becomes 1 x 50 = 50V.

Example for a fixed load resistance:



V_{set} = Voltage programmed
OVP_{set} = OverVoltage programmed
I_{set} = Current programmed

Required: - Fixed load resistance $R_{load} = 200\Omega$.
- Overcurrent protection disabled (OCP DIS).
- The V_{set} and I_{set} parameter have not been coupled.

- I_{set} = 0.1A Max. current through the load becomes 0.1A.

- OVP_{set} = 24V Overvoltage protection trip level becomes 24V.

Sequentially the voltages 14, 18, 22, and 26V will be programmed:

- V_{set} = 14V $I_{load} = V_{set} / R_{load} = 14 / 200 = 0.07A$.
The output channel stays in the CV mode.

- V_{set} = 18V $I_{load} = V_{set} / R_{load} = 18 / 200 = 0.09A$.
The output channel stays in the CV mode.

- V_{set} = 22V $I_{load} = V_{set} / R_{load} = 22 / 200 = 0.11A$. However, the maximum output current (0.1A) is going to be exceeded. Therefore, the current through the load becomes 0.1A and the voltage across the load is limited at 0.1 x 200 = 20V.
The output channel goes into the CC mode.

- I_{set} = 0.2A The maximum current through the load becomes 0.2A.
$I_{load} = V_{set} / R_{load} = 22 / 200 = 0.11A$. The voltage across the load becomes 0.11 x 200 = 22V.
The output channel goes back into the CV mode.

- V_{set} = 26V Now the overvoltage protection trip level OVP_{set} (24V) is going to be exceeded. This will activate the overvoltage protection circuitry, so the output voltage and current will be reduced to zero. Also the message OVERVOLTAGE will be displayed.

- OVP_{set} = 28V The overvoltage protection trip level becomes 28V.

- RESET The overvoltage protection circuitry is reset and the voltage across the load becomes 26V.
$I_{load} = V_{set} / R_{load} = 26 / 200 = 0.13A$.
The output channel remains in the CV mode.

5.5.3.1 Local control (in CV or CC mode)

The voltage V_{set} can be set using the [V] key and the numeric input keys.
Example:

Press the V key to start the voltage setting.
Press the keys 1, 2, . (dot), 3, 4 and ENTER to enter the setting of 12.34V.

The current I_{set} can be set using the [I] key and the numeric input keys.
Example:

Press the I key to start the current setting.
Press the keys 1, dot (.), 2, 3 and ENTER to enter the setting of 1.23A.

The overvoltage protection level OVP_{set} can be set using the [OVP] key and the numeric input keys.
Example:

Press the OVP key to initiate the overvoltage setting.
Press the keys 2, 0 and ENTER to enter the overvoltage setting of 20V.

The overcurrent protection can be enabled/disabled using the [OCP EN / OCP DIS] key.
Example:

Press the OCP EN/OCP DIS key.
IF OCP was enabled THEN OCP is disabled
ELSE OCP is enabled.
IF OCP has been enabled, the annunciator above the text OCP EN will be displayed.

An overcurrent or overvoltage trip protection can be reset by pressing the [RESET] key. Also the display of OVERCURRENT or OVERVOLTAGE will disappear.

In the CV mode the annunciator above the text CV will be displayed.

In the CC mode the annunciator above the text CC will be displayed.

5.5.3.2 Remote control (in CV or CC mode)

The voltage V_{set} can be programmed by the SOURCE subsystem command:
[:SOURce]:VOLTage[:LEVel][:IMMediate][:AMPLitude]
The voltage V_{set} can be requested by the SOURCE subsystem query:
[:SOURce]:VOLTage[:LEVel][:IMMediate][:AMPLitude]?
The output voltage can be read back by the MEASURE subsystem query:
:MEASure[:SCALar]:VOLTage[:DC]?
Example:

Send → :VOLT 12.34	Set 12.34V.
Send → :VOLT?	Send request voltage setting.
Read ← set_voltage	Read voltage setting.
Print set_voltage	Display voltage setting.
Send → :MEAS:VOLT?	Send readback query.
Read ← meas_voltage	Read output voltage.
Print meas_voltage	Display measured voltage.

The current I_{set} can be programmed by the SOURCE subsystem command:
[:SOURce]:CURRent[:LEVel][:IMMediate][:AMPLitude]
The current I_{set} can be requested by the SOURCE subsystem query:
[:SOURce]:CURRent[:LEVel][:IMMediate][:AMPLitude]?
The output current can be read back by the MEASURE subsystem query:
:MEASure[:SCALar]:CURRent[:DC]?
Example:

Send → :CURR 1.23	Set 1.23A.
Send → :CURR?	Send request current setting.
Read ← set_current	Read current setting.
Print set_current	Display current setting.
Send → :MEAS:CURR?	Send readback query.
Read ← meas_current	Read output current.
Print meas_current	Display measured current.

The overvoltage protection level OVP_{set} can be programmed by the SOURCE subsystem command: [:SOURce]:VOLTage:PROTection[:LEVel]
The overvoltage protection level OVP_{set} can be requested by the SOURCE subsystem query: [:SOURce]:VOLTage:PROTection[:LEVel]?
Example:

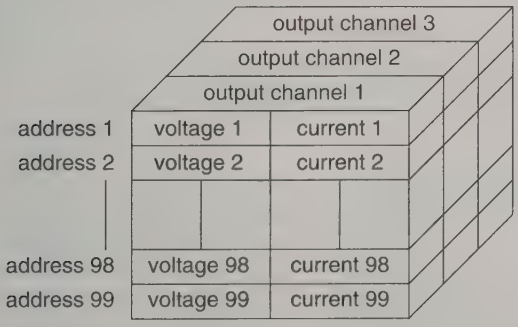
Send → :VOLT:PROT 20	Set 20.00 volt protection level.
Send → :MEAS:PROT?	Send readback query.
Read ← meas_over_voltage	Read overvoltage protection level.
Print meas_over_voltage	Display overvoltage protection level.

The overcurrent protection can be enabled/disabled by the SOURCE subsystem command: [:SOURce]:CURRent:PROTection:STATe
Example:

Send → :CURR:PROT:STAT ON	Enable overcurrent protection.
Send → :CURR:PROT:STAT OFF	Disable overcurrent protection.

5.5.4 Store/recall function

Your programmable power supply has a recall memory (battery back up), which is to be used for storing and recalling voltage and current settings of all output channels. The battery back up feature ensures that the stored values will be kept in memory during power-off. The recall memory consists of 99 addresses, numbered from 1 to 99. A recall memory address contains space for the voltage and current setting of all available output channels.



At delivery the contents of all addresses are set to their minimum value. When an address has been filled, its contents can be recalled, so that the settings become actual. The actual settings can be updated in OPERATE and STANDBY modes, but they are only active in the OPERATE mode. When the power supply is in the STANDBY mode, the actual settings will become active as soon as the OPERATE mode is entered.

Note: To remember which locations have been programmed and which have not, keep a record (such as the following) of which locations have been used.

MEMORY ADDRESS	OUTPUT CHANNEL 1		OUTPUT CHANNEL 2	
	VOLTAGE	CURRENT	VOLTAGE	CURRENT
01	20.0	0.00	15.9	0.90
02	19.9	0.10	15.8	0.80
03	19.8	0.20	15.7	0.70
04	etc.	etc.	etc.	etc.

5.5.4.1 Local control (store/recall)

The voltage V_{set} can be set using the [V] key and the numeric input keys.
The output voltage can be adjusted using the [- V +] key in the OPERATE mode.
The current I_{set} can be set using the [I] key and the numeric input keys.
The output current can be adjusted using the [- I +] key in the OPERATE mode.
The actual voltage/current setting can be stored using the [STORE] key.
The actual voltage/current setting can be recalled using the [RECALL] key.

Example:

- REQUIREMENTS : Fill the memory address 23 with 15V/0.3A and the memory addresses 33, 34, and 35 with, respectively, 20V/1A, 22V/1A and 24V/1A for output channel 1.
- SOLUTION:
  Press [OPR STBY] to make the STANDBY mode active.
  For multiple output units press [SELECT] a number of times until output channel 1 has been selected (see indication 1 on the display).
  Press [V] [1] [5] [ENTER] to set the actual voltage at 15V.
  Press [I] [•] [3] [ENTER] to set the actual current at 0.3A.
  Press [STORE] [2] [3] [ENTER] to store the 15V and 0.3A at memory address 23.

Press [V] [2] [0] [ENTER] to set the actual voltage at 20V.
Press [I] [1] [ENTER] to set the actual current at 1A.
Press [STORE] [3] [3] [ENTER] to store the 20V and 1A at memory address 33.
Press [V] [2] [2] [ENTER] to set the actual voltage at 22V.
Press [STORE] [3] [4] [ENTER] to store the 22V and 1A at memory address 34.
Press [V] [2] [4] [ENTER] to set the actual voltage at 24V.
Press [STORE] [3] [5] [ENTER] to store the 20V and 1A at memory address 35.
Verify the programmed memory addresses, using [RECALL] and the numeric input keys plus [V] and [I] keys, e.g.:
Press [RECALL] [2] [3] [ENTER]. Press [V] to verify the voltage of 15V. Press [I] to verify the current of 0.3A.

5.5.4.2 Remote control (store/recall)

The recall memory voltage can be programmed using the [:SOURce]:LIST:VOLTage command.

The recall memory current can be programmed using the [:SOURce]:LIST:CURRent command.

The actual memory address index (1 to 99) can be selected using the [:SOURce]:LIST:INDex[:NSELect] command.

Example:

- REQUIREMENTS : Fill the memory address 23 with 15V/0.3A and the memory addresses 33, 34, and 35 with, respectively, 20V/1A, 22V/1A and 24V/1A for output channel 1.
- SOLUTION:

Send → :INST:STAT OFF	STANDBY mode active.
Send → :INST:NSEL 1	Output channel 1 selected.
Send → :LIST:IND 23	Address 23 selected.
Send → :LIST:VOLT 15	
Send → :LIST:CURR 0.3	15V/0.3A stored at address 23.
Send → :LIST:IND 33	Address 33 selected.
Send → :LIST:VOLT 20,22,24	20V, 22V, and 24V, stored at respectively, the addresses 33, 34, and 35.
Send → :LIST:CURR 1,1,1	1A stored at the addresses 33, 34, and 35.

5.5.5 Step functions

When a list of memory addresses has been filled with voltage and current settings, it can be used in one of the following ways:

1) AUTO_STEP OFF:
   This will invoke the manual step function, i.e., the next step is initiated by the operator. For instance by manually stepping through a list of predefined voltages and currents, a test pattern of voltage and current settings will be generated. The manual stepping will be executed for all enabled output channels. Refer to section 5.5.5.1 "Manual step function".

2) AUTO_STEP ON:
   This will invoke the automatic step function, i.e. the next step is initiated when the interval time has expired. For instance by automatically stepping through a list of sequential voltages and currents, a voltage/current ramp function will be executed. The start and stop address of the sequential list and the interval time between two consecutive steps can be programmed.

Stepping can be done in one of the following ways:

3) CONTINUOUS_STEP OFF:
   The predefined sequence of memory addresses is executed only once.

4) CONTINUOUS_STEP ON:
   The predefined sequence of memory addresses is executed continuously, i.e., repeatedly from start to stop address.

Stepping will be executed for all enabled output channels. Refer to section 5.5.5.2 "Automatic step function".

5.5.5.1 Manual step function

The manual step function can be executed locally, using the [STEP] key.

The AUTO_STEP function can be set ON or OFF via the STEP MENU under the [AUX] key.

Example:

- REQUIREMENTS :
  Step manually through the predefined list of voltage and current settings, stored at the memory addresses 20 to 40. The voltage and current settings must be output for channel 1. Output channel 2 must be disabled.

- SOLUTION:
  Press [AUX] [ENTER] to enter the STEP submenu.
  Check that the AUTO STEP is OFF, or press the OFF (0) key to set the AUTO STEP function off.
  Press [ENTER] to leave the STEP submenu.
  Press [SELECT] (only for multiple output models) to select output channel 1.
  Press [ENABLE DISABLE] to enable output channel 1.
  Press [SELECT] (only for multiple output models) to select output channel 2.
  Press [ENABLE DISABLE] to disable output channel 2.
  Press [SELECT] as many times as necessary to select output channel 1 again.
  Press [OPR STBY] to make the OPERATE mode active.
  Press [STEP] to enter the step mode.
  Press [2] [0] [ENTER] to select start address 20 of the list.
  The display reads: `1 STEP 20 .......`
  LOOP: Press [V] if you want to see the actual voltage on output channel 1 at the memory address as indicated on the display.
  Press [I] if you want to see the actual current from output channel 1 at the memory address as indicated on the display.
  Press [STEP] to select the next memory address of the list. When memory address 41 is reached, exit the loop by pressing [◄].
  ENDLOOP
  Press [SELECT] to select output channel 2.
  The display reads: `2 STEP 41 DIS`

  Remark: When the next step is executed, the next voltage and current setting in the list is made active and output on channel 1.

5.5.5.2 Automatic step function

5.5.5.2.1 Local control (automatic stepping)

The AUTO STEP function, the CONTINUOUS STEP function, the step interval time, the START address, and the STOP address can be set via the [AUX] key.

The automatic step function can be started by pressing the [STEP] key.

Example:

- REQUIREMENTS:
  Step automatically through the predefined list of voltage and current settings stored at the memory addresses 20 to 40. When the end of the list is reached, it must start again at the beginning. The next voltage and current setting must be output for channel 1 at an interval time of 5 seconds.

- SOLUTION:
  Press [AUX] [ENTER] to enter the STEP submenu.
  Press [1] to set the AUTO STEP function on.
  Press [AUX] to set the TIME INTerval function.
  Press [5] [ENTER] to set the interval time at 5 seconds.
  Press [AUX] to set the CONTINUOUS step function.
  Press [1] to set the CONTINUOUS step function on.
  Press [AUX] to set the START AT function.
  Press [2] [0] [ENTER] to set the start address of the sequence list at 20.
  Press [AUX] to set the STOP AT function.
  Press [4] [0] [ENTER] to set the stop address of the sequence list at 40.
  Press [ENTER] to leave the AUX menu.
  Press [SELECT] (only for multiple output models) to select output channel 1.
  Press [ENABLE DISABLE] to enable output channel 1.
  Press [OPR STBY] to make the OPERATE mode active.
  Press [STEP] to enter the step mode.
  Press [2] [0] to select start address 20 of the list.
  The display reads : `1 STEP TO 20`
  Press [ENTER] to initiate the automatic stepping.
  - Check on the display that the memory address is automatically incremented every 5 seconds.
  - Exit the automatic stepping by pressing the (backspace) key. The last recalled voltage and current setting remain active.

5.5.5.2.2 Remote control (automatic stepping)

The actual memory address index (1 to 99) can be selected using the [:SOURce]:LIST:INDex[:NSELect] command. The selected memory address can be requested by means of the [:SOURce]:LIST:INDex[:NSELect]? query.

A sequence list of memory addresses can be defined using the [:SOURce]:LIST:SEQuence:STARt and [:SOURce]:LIST:SEQuence:STOP commands.
A sequence list of memory addresses can be reported using the [:SOURce]:LIST:SEQuence:STARt? and [:SOURce]:LIST:SEQuence:STOP? queries.

The length of a sequence list, i.e. the number of voltage and current points, can be requested by the [:SOURce]:LIST:VOLTage:POINts? and [:SOURce]:LIST:CURRent:POINts? queries.

The step interval time can be defined by the [:SOURce]:LIST:TIMer command and can be requested by the [:SOURce]:LIST:TIMer? query.

The source of the next step in the sequence list (the step trigger) can be defined and requested by the [:SOURce]:LIST:SOURce command, respectively the [:SOURce]:LIST:SOURce? query. The following sources are possible:

- If source = TIMer, the internal timer of the power supply is used to count the step interval time.
- If source = EXTernal or BUS, the active trigger source depends on whether the START line of the trigger bus at the rear of the power supply is active or not. If active, step pulses from the external STEP input will cause the next step to be performed. If not active, the next step will be performed after the *TRG command or after the GET trigger command.

The execution of a sequence list can be started using the :INITiate[:IMMediate] command. The first address is the START address and the last address is the STOP address.
A sequence list can be executed continuously by means of the :INITiate:CONTinuous command.
The execution of a sequence list can be stopped by means of the :ABORt command. If the execution is stopped, the last recalled voltage and current setting remain active.

Example:

- REQUIREMENTS:
  Step automatically through the predefined list of voltage and current settings, stored at the memory addresses 20 until 40. When the end of the list is reached, it must start again at the beginning. The next voltage and current setting must be output for channel 1 at an interval time of 5 seconds.

- SOLUTION:

Send → :LIST:SOUR TIM	The next step is automatically initiated by the internal timer.
Send → :LIST:TIM 5.0	Set the interval time at 5 seconds.
Send → :LIST:SEQ:START 20	Set the start address of the sequence list at 20.
Send → :LIST:SEQ:STOP 40	Set the stop address of the sequence list at 40.
Send → :INST:NSEL 1	Select output channel 1.
Send → :OUTP:STAT ON	Enable output channel 1.
Send → :INST:STAT ON	Make OPERATE mode active.
Send → :INIT:CONT ON	Set the CONTINUOUS step function on.
Send → :INIT	Initiate the automatic stepping.

.
Check the display of the power supply to verify that the memory address is automatically incremented every 5 seconds.
.

Send → :ABORT	Exit the automatic stepping.

Check that the last recalled voltage and current setting remain active.

5.5.5.3 External step functions

There are three SMB connectors at the rear: START, STEP, and READY.
The modes and functions of the connectors are shown in the following table.

NAME	MODE	FUNCTION
START	input	Enables stepping via the STEP input.
STEP	input	Executes the next step.
READY	output	Indicates whether a step is finished (ready for the next step).

SMB connector cables connect your power supply to the instrument that controls the step function. For preferred SMB cables, refer to section 2.4.2 "Optional accessories".

There is a standard GPIB interface connector at the rear. The GPIB interface software supports complete trigger capability. For preferred GPIB connector cabling, refer to section 2.4.2 "Optional accessories".

If the trigger source = TIMer, the internal timer of the power supply is used to count the interval time between two consecutive steps.
If the trigger source = EXTernal or BUS, the active trigger source depends on whether or not the START line of the trigger bus at the rear is active.

EXTERNAL STEPPING (via the trigger bus)
If the START line is active (LOW), step pulses from the external STEP input line will cause the next step to be performed.

EXTERNAL STEPPING (via the GPIB)
If the START line is not active (HIGH), the next step will be performed on the receipt of the *TRG command or the GET code via the GPIB.

Note: LOW = 0 to 0.8V and HIGH = 2 to 5V

5.5.5.3.1 Trigger bus control

External stepping via the trigger bus can be done in two ways:
1) In the synchronous mode:
In this mode all three bus signal lines have their own functionality.

2) In the asynchronous mode:
In this mode the READY line is externally connected to the START line.

To control the recall memory via the trigger bus, the STEP mode may not be automatic and the START input line must be pulled LOW. This will enable the STEP line to trigger the next step to be executed (external triggering). Pulling the START line LOW will also disable the manual STEP key.

When enabled, a STEP pulse will trigger the step mechanism. The leading edge of the STEP pulse makes the READY line active (LOW) within 100 nanoseconds. The READY line will be released when the internal processing is finished and the STEP line is HIGH. The internal processing time does not include the reprogramming delay time. It is the responsibility of the user to choose a STEP rate that is not too high for the power supply and its load condition, so that the output can settle within the STEP time.

Note: STEP pulses, received while the READY line is low, will be ignored.

5.5.5.3.2 GPIB control

GPIB control can only be done in the remote mode of operation. An external trigger can be programmed in the following ways:

- Send → *TRG — By sending the common command *TRG to the power supply.
- Send → GET — By sending the GET (Group Execute Trigger) code over the GPIB interface.

5.6 Advanced use

This section describs how to connect together output channels with the same ratings. In this way higher output powers through a connected load can be obtained.

To increase the total output current through a connected load, the output channels have to be connected in parallel. Refer to section 5.6.1.

To increase the total output voltage over a connected load, the output channels must be connected in series. Refer to section 5.6.2.

This section also describs the way to connect more than one load to an output channel (multiple loads). Refer to section 5.6.3.

CAUTION: Only output channels with equivalent voltage and current ratings may be connected in series or parallel.

5.6.1 Parallel connection of output channels

Connecting output channels in parallel provides a greater current capability than can be obtained from a single output channel. In principle you can put more than two output channels in parallel.

Output channels in parallel configurations can operate in either Constant Voltage (CV) or in Constant Current (CC).

When channels are connected in parallel with the intention to increase the current capability, it is advised to set all channels to the same voltage. When the channels have the same power characteristics, also set them to the same current value.

In general, you can handle the following procedure.

- Before making any connections, set the power supply into STANDBY.
- Connect the channels in parallel.

If a constant voltage is required accross the load, proceed as follows.

- Program the voltage setting of all channels equal to the constant voltage required.
- Calculate the maximum current needed for the load (I_{max}). Count with the minimum value of R_{load}.
- Program the current setting of the individual channels such that the sum of the values is equal to I_{max}.
- Now you may set the power supply into the operate mode.

If a constant current is required through the load, proceed as follows.

- Program the current setting of the individual channels such that the sum of the values is equal to the value of the constant current required.
- Calculate the maximum voltage needed to supply the constant current. Count with the maximum value of R_{load}.
- Program the voltage setting of all channels equal to the maximum voltage needed.
- Now you may set the power supply into the operate mode.

If constant voltage nor constant current is required you may program typical values as well.

There are two ways of sensing the load when connecting output channels in parallel: local sensing and remote sensing.

5.6.1.1 Local sensing (outputs in parallel)

Connecting the load wires directly to the +V and -V terminals of output channel 2 keeps the number and the total length of the load wires to a minimum. The following diagram shows the wiring scheme.

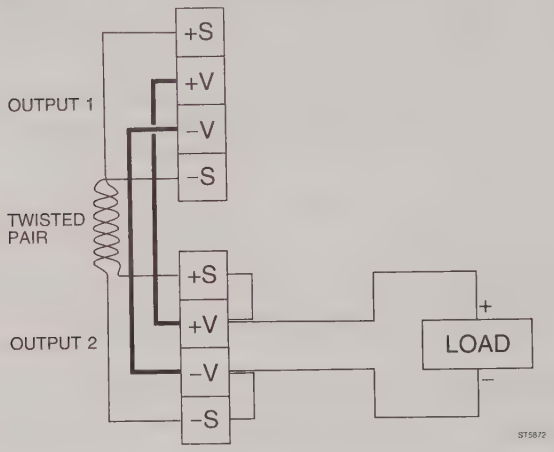


Figure 5.6.1 Local Sensing with Two Outputs in Parallel

CAUTION: To prevent noise pickup, twist the sense wires and shield them from the environment.

5.6.1.2 Remote sensing (outputs in parallel)

The sense wires are connected from the load to the +S and -S terminals of output channel 2. This compensates for the voltage drop in the wires from the load to the +V and -V terminals. The following diagram shows the wiring scheme.

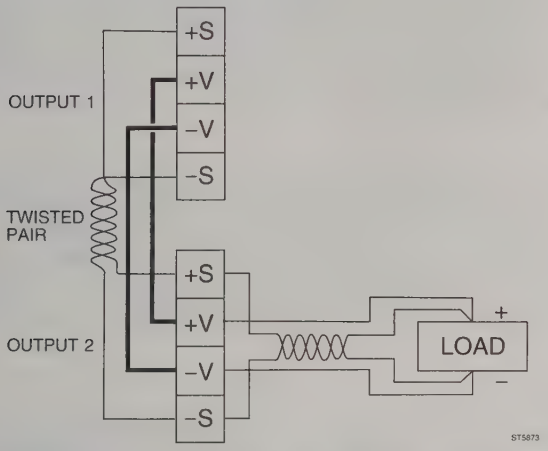


Figure 5.6.2 Remote Sensing with Two Outputs in Parallel

CAUTION: To prevent noise pickup, twist the sense wires and shield them from the environment.

5.6.2 Serial connection of output channels

Connecting output channels in series provides a greater voltage capability than can be obtained from a single output channel. In principle, you can put more than two output channels in series. However, there is the limitation that the total maximum voltage of each terminal may not exceed 240V with respect to the ground.

Output channels in serial configurations can operate in either Constant Voltage (CV) or in Constant Current (CC).

CV OPERATION

For CV operation all output channels must be in the CV mode. Program the current setting of all output channels to the desired current limit point. Then program the voltage setting of each output channel, so that the sum of all voltages equals the total desired operating voltage. The simplest way to accomplish this is to program each output channel to an equal part of the total desired operating voltage, e.g., three output channel settings of 25 V in series provide 75 V.

CC OPERATION

For CC operation the current setting of each output channel must be programmed to the desired operating current. The sum of the voltage settings determines the voltage limit points. As an example, consider two output channels in series (refer also to section 5.6.2.1). Program the voltage setting of both output channels to one half of the total voltage limit point. At load voltages < $^1/_2$ of the total voltage limit point, one output channel will operate in the CC mode. At load voltages > $^1/_2$ of the total voltage limit point, the output channel that was in the CC mode will change to the CV mode, while the other output channel will regulate the current in the CC mode and provide the balance of the voltage required by the load.

Note that the total voltage over the load is the sum of the individual readback output voltages, provided the load voltage < $^1/_2$ of total voltage limit point.

WARNING: To guarantee the safe use of the power supply, the total maximum voltage at each terminal may not exceed 240V with respect to ground.

There are two ways of sensing the load when connecting output channels in series, i.e., local sensing and remote sensing.

5.6.2.1 Local sensing (outputs in series)

Connect the load wires to the +V terminal of output channel 1 and the -V terminal of output channel 2, and interconnect the -V terminal of output channel 1 and the +V terminal of output channel 2. Connecting the +S of output channel 2 to the -S of output channel 1, while removing the local sense jumper between +S and +V of output channel 2, will compensate for the voltage drop across the wires from output channel 2 to output channel 1. The following diagram shows the wiring scheme.

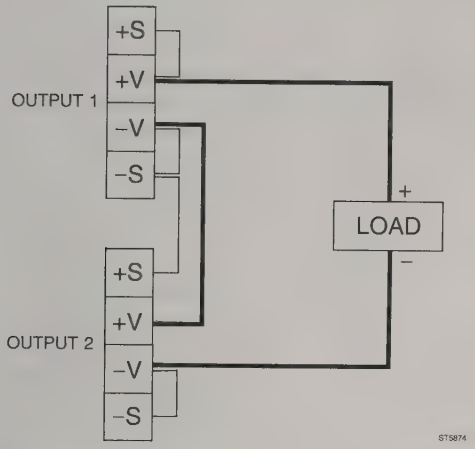


Figure 5.6.3 Local Sensing with Two Outputs in Series

5.6.2.2 Remote sensing (outputs in series)

Connecting extra sense wires from the load to the +S terminal of output channel 1 and the -S terminal of output channel 2 compensates for the voltage drop in the wires from the load to the +V and -V terminals. Connecting the +S of output channel 2 to the -S of output channel 1, while removing the local sense jumper between +S and +V of output channel 2, will compensate for the voltage drop across the wires from output channel 2 to output channel 1.The following diagram shows the wiring scheme.

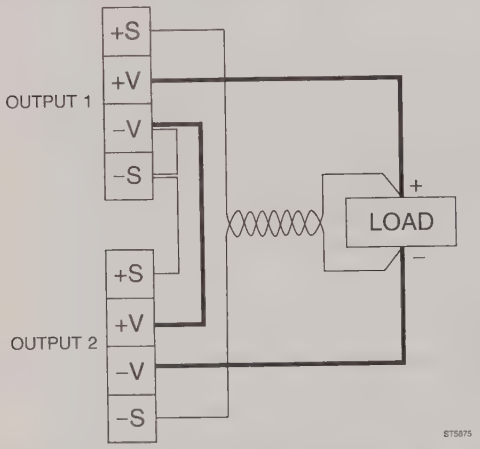


Figure 5.6.4 Remote Sensing with Two Outputs in Series

CAUTION: To prevent noise pickup, twist the sense wires and shield them from the environment.

5.6.3 Parallel connection of loads

If more than one load is connected to an output channel, use separate wires to connect each load. This minimizes mutual coupling effects and takes full advantage of the power supply's low output impedance. Each pair of wires should be as short as possible to reduce wire inductance and noise pickup. The loads must be connected in parallel, not in series so that loads are not mutually influenced by load fluctuations.

It is advised to use a pair of DC distribution terminals (DT) not located at the output channel terminals.

Note: In principle there is no restriction about the number of loads that can be connected. Remote voltage sensing is recommended if one load is more sensitive than the other(s); therefore, sense directly at the most sensitive load.

5.6.3.1 Local sensing (loads in parallel)

The following diagram shows the wiring scheme.

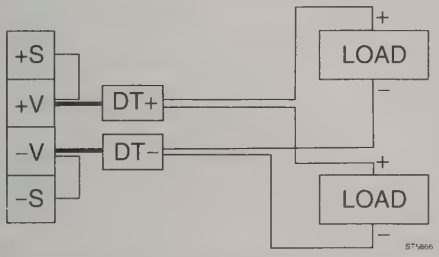


Figure 5.6.5 Local Sensing withTwo Loads in Parallel

If local sensing is used, locate the distribution terminals (DT) as near as possible to the output channel terminals.

5.6.3.2 Remote sensing (loads in parallel)

The following diagram shows the wiring scheme.

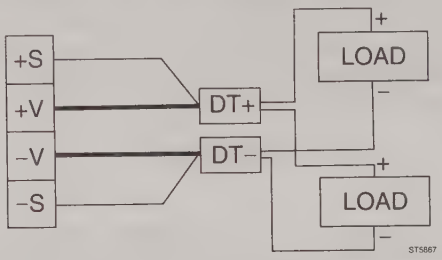


Figure 5.6.6 Remote Sensing withTwo Loads in Parallel

If remote sensing is used, locate the distribution terminals (DT) as near as possible to the load terminals.

CAUTION: To prevent noise pickup, twist the sense wires and shield them from the environment.

APPENDIX A ACCESSORIES

A.1 Supplied with the instrument

- Operation manual English : 4822 872 80165
- Reference manual English : 4822 872 80168
- Operation manual German : 4822 872 80166
  (only in EURO and SWISS)
- Operation manual French : 4822 872 80167
  (only in EURO, SWISS and USA)
- Programming Card English : 4822 872 80098
- Power cord EURO : 5322 321 23297
  SWISS : 5322 321 10679
  UK : 5322 321 10681
  USA : 5322 321 10644
- Two spare fuses
- Two mounting brackets

A.2 Optional

The following accessories can be ordered via your sales representative:

	Typeno:
• GPIB IO software drivers (for PC)	PM2201/0x
• GPIB IO software drivers (for PS/2)	PM2202/0x
• GPIB interface board (for PC)	PM2201/0x or PM2201/9x
• GPIB interface board (for PS/2)	PM2202/0x or PM2202/9x
• GPIB interface cables (0.5 meter long)	PM2295/05
• GPIB interface cables (1.0 meter long)	PM2295/10
• GPIB interface cables (2.0 meter long)	PM2295/20
• 19" Rack mount (with other 19" units)	PM9280/03
• SMB cable set	PM2392/01

consists of:
- 100 cm cable.
- 25 cm cable.
- T-male piece.
- Adapter to BNC.

APPENDIX B
SCPI CONFORMANCE INFORMATION

This instrument complies to the SCPI standard version 1990.0. The following classes of commands and queries have been implemented:

B.1 IEEE 488.2-1987

*CLS
*ESE
*ESE?
*ESR?
*IDN?
*OPC
*OPC?
*PSC
*PSC?
*RCL
*RST
*SAV
*SRE
*SRE?
*STB?
*TRG
*TST?
*WAI

B.2 SCPI Std 1990.0 Confirmed

:ABORT

:CALIBRATION:STATE
:CALIBRATION:STATE?
:CALIBRATION:VALUE
:CALIBRATION:AUTO

:DISPLAY:ENABLE
:DISPLAY:ENABLE?
:DISPLAY:CONTRAST

:DISPLAY:CONTRAST?
:DISPLAY:WINDOW:TEXT:DATA
:DISPLAY:WINDOW:TEXT:DATA?

:INITIATE:IMMEDIATE
:INITIATE:CONTINUOUS
:INITIATE:CONTINUOUS?

:INSTRUMENT:SELECT
:INSTRUMENT:SELECT?
:INSTRUMENT:NSELECT
:INSTRUMENT:NSELECT?
:INSTRUMENT:DEFINE
:INSTRUMENT:DEFINE?
:INSTRUMENT:DELETE:NAME
:INSTRUMENT:DELETE:ALL
:INSTRUMENT:CATALOG?
:INSTRUMENT:STATE
:INSTRUMENT:STATE?

:MEASURE:SCALAR:VOLTAGE:DC?
:MEASURE:SCALAR:CURRENT:DC?

:OUTPUT:STATE
:OUTPUT:STATE?
:OUTPUT:PROTECTION:TRIPPED?
:OUTPUT:PROTECTION:CLEAR

:SOURCE:CURRENT:LEVEL:IMMEDIATE:AMPLITUDE
:SOURCE:CURRENT:LEVEL:IMMEDIATE:AMPLITUDE?
:SOURCE:CURRENT:LIMIT:HIGH?
:SOURCE:CURRENT:LIMIT:LOW?
:SOURCE:CURRENT:PROTECTION:TRIPPED?
:SOURCE:CURRENT:PROTECTION:STATE
:SOURCE:CURRENT:PROTECTION:STATE?
:SOURCE:VOLTAGE:LEVEL:IMMEDIATE:AMPLITUDE
:SOURCE:VOLTAGE:LEVEL:IMMEDIATE:AMPLITUDE?
:SOURCE:VOLTAGE:LIMIT:HIGH?
:SOURCE:VOLTAGE:LIMIT:LOW?
:SOURCE:VOLTAGE:PROTECTION:LEVEL
:SOURCE:VOLTAGE:PROTECTION:LEVEL?
:SOURCE:VOLTAGE:PROTECTION:TRIPPED?
:SOURCE:POWER:LIMIT:HIGH?

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:SOURCE:FUNCTION:MODE?
:SOURCE:LIST:VOLTAGE
:SOURCE:LIST:VOLTAGE:POINTS?
:SOURCE:LIST:CURRENT
:SOURCE:LIST:CURRENT:POINTS?
:SOURCE:LIST:GENERATION
:SOURCE:LIST:GENERATION?

:STATUS:OPERATION:EVENT?
:STATUS:OPERATION:CONDITION?
:STATUS:OPERATION:ENABLE
:STATUS:OPERATION:ENABLE?
:STATUS:OPERATION:PTRANSITION
:STATUS:OPERATION:PTRANSITION?
:STATUS:OPERATION:NTRANSITION
:STATUS:OPERATION:NTRANSITION?
:STATUS:OPERATION:INSTRUMENT:EVENT?
:STATUS:OPERATION:INSTRUMENT:CONDITION?
:STATUS:OPERATION:INSTRUMENT:ENABLE
:STATUS:OPERATION:INSTRUMENT:ENABLE?
:STATUS:OPERATION:INSTRUMENT:PTRANSITION
:STATUS:OPERATION:INSTRUMENT:PTRANSITION?
:STATUS:OPERATION:INSTRUMENT:NTRANSITION
:STATUS:OPERATION:INSTRUMENT:NTRANSITION?
:STATUS:OPERATION:INSTRUMENT:ISUMMARY:EVENT?
:STATUS:OPERATION:INSTRUMENT:ISUMMARY:CONDITION?
:STATUS:OPERATION:INSTRUMENT:ISUMMARY:ENABLE
:STATUS:OPERATION:INSTRUMENT:ISUMMARY:ENABLE?
:STATUS:OPERATION:INSTRUMENT:ISUMMARY:PTRANSITION
:STATUS:OPERATION:INSTRUMENT:ISUMMARY:PTRANSITION?
:STATUS:OPERATION:INSTRUMENT:ISUMMARY:NTRANSITION
:STATUS:OPERATION:INSTRUMENT:ISUMMARY:NTRANSITION?
:STATUS:PRESET
:STATUS:QUEUE:NEXT?
:STATUS:QUESTIONABLE:EVENT?
:STATUS:QUESTIONABLE:CONDITION?
:STATUS:QUESTIONABLE:ENABLE
:STATUS:QUESTIONABLE:ENABLE?
:STATUS:QUESTIONABLE:PTRANSITION
:STATUS:QUESTIONABLE:PTRANSITION?
:STATUS:QUESTIONABLE:NTRANSITION
:STATUS:QUESTIONABLE:NTRANSITION?
:STATUS:QUESTIONABLE:INSTRUMENT:EVENT?

:STATUS:QUESTIONABLE:INSTRUMENT:CONDITION?
:STATUS:QUESTIONABLE:INSTRUMENT:ENABLE
:STATUS:QUESTIONABLE:INSTRUMENT:ENABLE?
:STATUS:QUESTIONABLE:INSTRUMENT:PTRANSITION
:STATUS:QUESTIONABLE:INSTRUMENT:PTRANSITION?
:STATUS:QUESTIONABLE:INSTRUMENT:NTRANSITION
:STATUS:QUESTIONABLE:INSTRUMENT:NTRANSITION?
:STATUS:QUESTIONABLE:INSTRUMENT:ISUMMARY:EVENT?
:STATUS:QUESTIONABLE:INSTRUMENT:ISUMMARY:CONDITION?
:STATUS:QUESTIONABLE:INSTRUMENT:ISUMMARY:ENABLE
:STATUS:QUESTIONABLE:INSTRUMENT:ISUMMARY:ENABLE?
:STATUS:QUESTIONABLE:INSTRUMENT:ISUMMARY:PTRANSITION
:STATUS:QUESTIONABLE:INSTRUMENT:ISUMMARY:PTRANSITION?
:STATUS:QUESTIONABLE:INSTRUMENT:ISUMMARY:NTRANSITION
:STATUS:QUESTIONABLE:INSTRUMENT:ISUMMARY:NTRANSITION?

:SYSTEM:KLOCK
:SYSTEM:KLOCK?
:SYSTEM:ERROR?
:SYSTEM:SET
:SYSTEM:SET?
:SYSTEM:VERSION?

B.3 SCPI approved

:SOURCE:CURRENT:LEVEL:IMMEDIATE:AMPLITUDE:AUTO
:SOURCE:CURRENT:LEVEL:IMMEDIATE:AMPLITUDE:AUTO?
:SOURCE:VOLTAGE:LEVEL:IMMEDIATE:AMPLITUDE:AUTO
:SOURCE:VOLTAGE:LEVEL:IMMEDIATE:AMPLITUDE:AUTO?

B.4 SCPI syntax and style

REMARK: It is advised to use the :SYSTEM:VERSION command to control compatibility of the application program with respect to the SCPI implementation of the programmable power supply used. This is helpful for future SCPI compatibility.

:OUTPUT:PROTECTION:COUPLING:INSTRUMENT
:OUTPUT:PROTECTION:COUPLING:INSTRUMENT?
:OUTPUT:PROTECTION:COUPLING:STATE
:OUTPUT:PROTECTION:COUPLING:STATE?

:SOURCE:CURRENT:PROTECTION:DELAY
:SOURCE:CURRENT:PROTECTION:DELAY?
:SOURCE:LIST:INDEX:NSELECT
:SOURCE:LIST:INDEX:NSELECT?
:SOURCE:LIST:SEQUENCE:START
:SOURCE:LIST:SEQUENCE:START?
:SOURCE:LIST:SEQUENCE:STOP
:SOURCE:LIST:SEQUENCE:STOP?
:SOURCE:LIST:TIMER
:SOURCE:LIST:TIMER?
:SOURCE:LIST:SOURCE
:SOURCE:LIST:SOURCE?

:SYSTEM:UNPROTECT:STATE
:SYSTEM:UNPROTECT:STATE?
:SYSTEM:UNPROTECT:SELECT
:SYSTEM:UNPROTECT:SELECT?
:SYSTEM:UNPROTECT:PWORD
:SYSTEM:POCLEAR
:SYSTEM:POCLEAR?
:SYSTEM:VERSION

:TEST:INSTRUMENT?
:TEST:SYSTEM?

APPENDIX C
ABBRIVIATIONS, SYMBOLS & TERMS

C.1 ABBREVIATIONS

- ac = Alternating current
- ADDA = Analog/Digital - Digital/Analog
- AH = Acceptor Handshake
- AMPL = Amplitude
- ANSI = American National Standards Institute
- AUX = Auxilliary

- BNC = Bayonet Normal Connector

- CAL = Calibration
- CAT = Catalog
- CC = Constant Current
- CLE = Clear
- CLS = Clear screen or Clear status
- CISPR = Comité International Special des Pertubations Radioélectriques
- COND = Condition
- CONF = Configuration or configure
- CONT = Contrast
- COUP = Coupling
- CP = Coupled Parameters
- CPU = Central Processor Unit
- CSA = Canadian Standards Association
- CURR = Current
- CV = Constant Voltage

- dc = Direct current
- DEF = Define or default
- DEL = Delete or delay
- DEN = Display enable
- DIAG = Diagnostics
- DIS(AB) = Disable
- DISP = Display
- DT = Device Trigger

- EMC = Electro Magnetic Compatibility

- EMI = Electro Magnetic Interference
- EMS = Electro Magnetic Susceptibility
- EN(AB) = Enable
- ERR = Error
- ESB = Event Summary Bit
- ESE = Event Status Enable
  ESR = Event Status Register
- EURO = Europa
- EVEN = Event
- EXT = External

- FL = Failure
- FLT = Fault
- FUNC = Function

- GEN = Generation
- GET = Group Execute Trigger
- GPIB = General Purpose Interface Bus

- IEC = International Electrotechnical Commission
- IEEE = Institute of Electrical and Electronic Engineers
- IDN = Identification
- IMM = Immediate
- IND = Index
- INIT = Initiate
- INST = Instrument
- INT = Internal
- I/O or IO = Input Output
- ISUM = Instrument summary

- KLOC = Keyboard lock

- LCD = Liquid Crystal Display
- LCL = Local
- LEV = Level
- LIM = Limit
- LRN = Learn
- LSB = Least Significant Bit
- LSD = Least Significant Digit

- MAV = Message available
- MAX = Maximum
- MEAS = Measure(ment)

- MIL = Military
- MIN = Minimum
- MOD = Mode
- MSB = Most Significant Bit
- MSD = Most Significant Digit
- MSS = Master Summary Status
- MTBF = Mean Time Between Failures
- MTTR = Mean Time To Repair

- NRF = Numeric forgiving
- NSEL = Numeric select
- NTR = Negative transition

- OC(P) = Overcurrent (Protection)
- OPC = Operation complete
- OPR = Operate
- OPER = Operation
- OPT = Option
- OUTP = Output
- OV(P) = Overvoltage (Protection)

- PARD = Periodic And Random Deviation
- PC = Personal Computer
- PMT = Program Message Terminator
- PON(C) = Power ON (Clear)
- POW = Power
- pp = peak to peak
- PPS = Programmable Power Supply
- PROT = Protection
- PS = Personal System
- PSC = Power on Status Clear
- PTR = Positive transition
- PWOR = Password

- QUES = Questionable

- RAM = Random Access Memory
- RCL = Recall
- REM = Remote
- RFI = Radio Frequency Interference
- rms = root mean square
- ROM = Read Only Memory
- RQS = Request Service

- RST = Reset

- S = Sense
- SAV = Save
- SCAL = Scalar
- SCPI = Standard Commands for Programmable Instruments
- SEL = Select
- SEQ = Sequence
- SRE = Service Request Enable
- SR(Q) = Service Request
- SOUR = Source
- STAT = State
- STB = Status byte
- STBY = Standby
- STP = Step
- SYST = System

- TC = Temperature Coefficient
- TRG = Trigger
- TRIP = Tripped
- TST = Test

- UK = United Kingdom
- UL = Underwriters Laboratories
- UNPR = Unprotect
- UNR = Unregulated
- USA = United States of America

- VAL = Value
- VDE = Verband Deutscher Elektrotechniker
- VERS = Version
- VOLT = Voltage

- WIND = Window

C.2 GLOSSARY OF SYMBOLS

- % = percentage
- * = begin of a common command/query
- , = separation sign for commands/queries
- : = begin of a subsystem command/query part
- ? = end of a query
- ° = degree (e.g. °C =degree Celsius)
- A = Ampere
- C = Celsius
- d = differentiate, e.g. di (derived current)
- ft = foot
- g = gravity (m/s^2)
- Hz = Hertz
- I = current
- K = Kelvin
- m = meter
- mA = milliampere
- ms = millisecond
- mV = millivolt
- MHz = Megahertz
- OC = Overcurrent
- OV = Overvoltage
- P = Power
- R = Resistance
- s = second
- t = time
- µ = micro, e.g., µs
- U = voltage
- V = Volt
- W = Watt
- Z = Impedance
- [. . .] = command/query part that may be omitted (default node)
- { . . . } = command/query part that can be repeated
- | = sign to indicate a choice (. . . or . . .)

C.3 GLOSSARY OF TERMS

AUTORANGING
A power supply is autoranging if it can supply the maximum rated power over the continuous range of voltage and current.

CALIBRATION MODE
In this mode the power supply can be adjusted to comply with external calibration standards.

DRIFT
The maximum change of the regulated output voltage or current during an 8-hour period (long term drift), following a 30-minute warming-up (short term drift). All influence and control quantities must remain constant during these periods. Drift includes both random and periodic deviations over the bandwidth from zero frequency (DC) to the upper frequency limit.

LOAD EFFECT (load regulation)
The load effect is the maximum change in the steady state of the regulated output voltage or current, resulting from a full load change in the load current of a CV supply or in the load voltage of a CC supply.

LOCAL MODE (opposite of the REMOTE mode)
In this mode the power supply can be operated locally via the keypad control keys.

LOCAL SENSING
The voltage is sensed directly at the power supply terminals. The power supply is shipped from the factory with local sensing.

OPERATE MODE (opposite of the STANDBY mode)
In this mode the power supply is able to deliver power.

PARD (ripple and noise)
Periodic And Random Deviation of the DC output voltage or current from its average value over a specified bandwidth. All influence and control quantities must remain constant.

PROGRAMMING ACCURACY
Maximum deviation between the programmed value and the actual output value (at calibration temperature $\pm$ 2°C).

PROGRAMMING RESOLUTION
Average programming step size. That is the smallest change that can be obtained either using the front panel keys or a controller.

PROGRAMMING RESPONSE TIME
The maximum time for the output to settle to a programmed value within a settling band, after having finished executing the settle command.

READBACK ACCURACY
Maximum error in the readback value of an output voltage or current (at calibration temperature ± 2°C).

REMOTE MODE (opposite of the LOCAL mode)
In this mode the power supply is programmed remotely from your PC via the GPIB.

REMOTE SENSING
A way of sensing by which a power supply monitors the voltage directly at the load via the extra sensing wires. The resulting circuit action compensates for the voltage drop in the wires to the load up to a maximum of 1 volt total.

SOURCE EFFECT (line regulation)
The maximum change in the steady state of the regulated output voltage or current, resulting from any change in the AC voltage source within the specified values.

STANDBY MODE (opposite of the OPERATE mode)
In this mode the power supply is operable, but the output channels are disabled (no power is supplied).

TEMPERATURE COEFFICIENT
The maximum change in the regulated output voltage or current per degree Celsius following a change in the ambient temperature after a 30 minutes warmup time.

APPENDIX D
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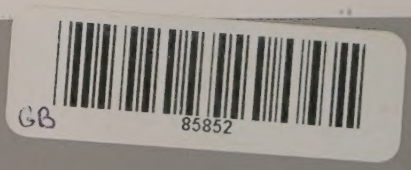
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